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Introduction

Histological studies are made for a definite purpose: to help collect evidences from which to develop accurate . . . .
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oncepts of the structure and behavior . . . .
with this information and build up concepts of the functioning of whole organs and systems.

Each living animal lives in four dimensions: three of space and one of time. At any moment, each feature of an animal's anatomy exists in the three space dimensions. But many features of the spatial architecture undergo rapid or slow cyclical, intermittent, or progressive changes with time. The chemical and physical characteristics, the shapes, the magnitudes, and the positions of structures change as parts of development, of physiology, and of pathology. New structures appear and old ones disappear. These are changes along the time dimension.

A histological section is not the original living material. It is only a two-imension slice out of a four-dimension system, minus what has been lost and plus what has been added in its preservation and preparation for study. From mental pictures of serial sections, we construct some aspects of our concepts of the three dimensions of living structures. To get concepts of the changes of structures with time, we often select a group of animals, attempt o treat them all alike, hope they all respond alike in direction, degree, and ate, kill a few after selected time intervals, make two-dimension sections from ach animal, and, from the resulting static pictures, by constructive imagina-ion, synthesize mental concepts of life processes.

A course in histology has at least two major purposes: (1) To help the tudent begin to understand the structure and functioning of living things, and 2) to give the student mental pictures of the two-dimension slices of "normal" organs. These picture-concepts of "normal" organs serve as a base line against which to recognize and judge the abnormality of obviously altered organs. Each of these major purposes demands that the student shall be able to recognize as many dead tissues as possible, that he have firmly in mind the salient characteristics of each tissue and organ. For developing concepts of living microscopic anatomy, it is just as important for one to know the structure of tissues and organs as it is for a mathematician to know the multiplication table, or the relationships commonly expressed in elementary algebra. The

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1

How to Identify Tissues and Organs

Introduction

In commencing a laboratory study of histology, one usually experiences great difficulty in selecting out of the confusing abundance of information that which is most helpful for the purpose of recognizing tissues. This Outline has been designed to overcome these difficulties.

An outline of this sort, however, has certain limitations. While only the principal characteristics of tissues and organs have been included, with some emphasis on identification characters, it cannot be too strongly emphasized that the more complete information one has about an organ the better one is prepared for an accurate diagnosis of a complex of tissues.

The beginning student in histology is likely to fall into the error of considering one good "spotting" character for a tissue sufficient, but nothing could be more erroneous than this idea; identification work is not that simple. It should be remembered that tissues are subject to the variations which occur in all living things, and constant exceptions will be found to almost any generalization. Also, the possibility must be considered that in any given section a favorite identifying character may be absent. For example, pancreas may be identified positively by the presence of the islands of Langerhans; but if a section does not possess islands, then the tissue is easily confused with parotid, unless one is fortified with a complete knowledge of the histology of the organ. Then, too, the histology of organs varies in different animals, depending on how far the animals are removed from one another phylogenetically Despite the desirability of knowing as much as possible about the histological structure of the organ to be identified, the author has acceded to a general student demand that some of the most diagnostic characters be italicized.

For the benefit of medical students who look forward to work in pathology, it may be said that certain tissues and organs show profound changes under the influence of disease. For instance, in fatty atrophy of the pancreas, only islands of Langerhans may be present; or, in voluntary muscle, only the neuromuscular spindles may persist. One who knows the neuromuscular spindles will recognize the area in which one is found as a region of striated muscle even though no contractile fiber is present. Again, under the influence of postmortem changes, only the stroma of organs may persist. Thus spleen can be recognized by the persistence of the characteristic trabeculae even though no stainable

nuclei remain to identify the splenic pulp cells. In pathology it is necessary to know the diagnostic characteristics which are most likely to persist when the organ is seriously altered by disease.

The descriptions given here are based largely on the tissues of man and other higher vertebrates; and, unless otherwise specified, the stain referred to is hematoxylin and eosin.

Methods of Microscopic Identification of Tissues and Organs

Tissues and organs are recognized in two ways: (1) *by superficial recognition of tissues, the picture made by the tissue as a whole;* (2) *by recognition of elements: the tissue elements are first identified, then a deduction is made as to the tissue's identity.*

The Superficial Recognition Method

This is a poor method, and too often used by the beginning student of histology. It depends entirely on visual memory of the general pattern made by the tissues of a structure; the tissue is identified as parotid gland because it looks like it. This method is likely to fail if there is something about the histological picture which makes it appear unfamiliar. Unfamiliarity may be due to three causes: (1) the inclusion of structures not normally present; (2) the exclusion of parts usually present; and (3) the presentation of familiar parts in a new way. Thus a tissue may be readily recognized when stained with hematoxylin and eosin, but if stained with only iron hematoxylin it may be very difficult to identify because of the difference in color pattern.

While a student may be able to identify correctly 95 per cent of the histological preparations in a set of slides which he has studied, he may be able to identify only 50 per cent in an identification test with other slides. The differences between these two scores result from the student having learned to diagnose his own histological preparations by purely superficial means; he identifies tissues by color, shape of section, or something else besides the form and arrangement of tissue elements. A good way to test one's dependence on superficial characters is to place a piece of colored cellophane in the blue glass carrier underneath the Abbe condenser of the microscope. This changes the color of the preparation. The difficulty now encountered in identification is in direct ratio to the superficial methods which have previously been used. Another way to overcome the tendency to make superficial identifications is to write out a list of the structures observed in a preparation before making a histological diagnosis.

The Recognition-of-elements Method

This method, which is employed by all good histologists, is as follows:

1. Look at the preparation with either the naked eye or with a reversed ocular to see whether it is composed of one or more types of tissue. Often some general idea may be gained as to the size and shape of the parts of certain organs.

2. Examine the section under a low-power (32-mm.) objective, using a low-power eyepiece. Identify as many of the different kinds of tissues as possible. Then note carefully the relationship of the various tissues to one another. Many organs can be identified with such an examination, but they should also be examined with a higher power for confirmation of diagnosis. Since most medical microscopes are not equipped with a 32-mm. objective, it may be necessary to omit this step.

3. Examine the section under a two-thirds-inch (16-mm.) objective, using a low-power eyepiece. If possible, study the cellular character of the tissue. Often the cellular structure is not distinct, yet much may be told about the general cellular nature from the position and relation of the nuclei to one another.

Methodically examine the cells in different parts of the specimen. Classify them according to the relative area occupied by cells and by matrix. If the matrix is small in amount, the cells are probably epithelial or glandular. If the cells are surrounded by much matrix, connective tissue is indicated. It may sometimes be found desirable to use a higher power than a 16-mm. objective and a 10x ocular for a detailed study of cells, but this is rarely the case.

4. Keep the different classes of fundamental tissues in mind, and mentally visualize the arrangement of the different tissues of the preparation under consideration.

The various regions of the body where such tissues could occur in close apposition are now thought of in turn. Each of such tissues or organs has certain special features. The specimen should now be examined for the presence of these special features. *By a process of elimination of the impossible, identity of the tissue or organ is determined.* Failure to identify a satisfactory preparation by this method will mean that the student does not know the fundamental tissues, or that he has an inadequate knowledge of special histology.

2

Cell

Cells are the biological building stones of all tissues. Most cells consist of a small mass of protoplasm enclosed in a membrane, and containing a nucleus. Some cells are multinucleated.

Cell Structure

A. CYTOPLASM (CYTOSOME).

This constitutes the protoplasm of a cell, exclusive of the nucleus. It is usually bound externally by a thin membrane. Within the cytoplasm are numerous bodies which may be divided into two separate categories as follows:

1. ORGANOIDS. These bodies are differentiated parts of the cytoplasm. They are actually living protoplasm.
   a. CENTRAL BODY (CENTROSOME, CELL CENTER, ATTRACTION SPHERE). When present it lies near the nucleus. Central body consists of a sphere of clear cytoplasm, the centrosphere, in which lie one or two dark staining granules, the centrioles. These are readily demonstrated with iron hematoxylin. The terminology for the central body is not standardized; hence, there has developed a confusing synonymy. Some authors use the term centrosome synonymously with centriole.
   b. CHONDRIOSOMES ("MITOCHONDRIA"). These are granular or rodlike structures which stain in living tissues with Janus green.
   c. GOLGI APPARATUS. It usually consists of a meshwork of fibrils which can be impregnated with either osmic acid or silver.
   d. FIBRILS (FIBRILLAE). Definite fibrils are observed in muscle and nerve cells. The fibril, however, is not now regarded as a part of the fundamental structure of all protoplasm.
2. METAPLASTIC INCLUSIONS. Products of the cell's metabolism. These are generally regarded as nonliving substances.
   a. SECRETION GRANULES.
   b. CARBOHYDRATES. Chiefly in the form of granules of glycogen.
   c. FATS AND LIPOIDS. In fixed and stained tissues these have usually been dissolved, leaving empty spaces in the cytoplasm.
   d. PIGMENT. Colored granules occur in some cells. Melanin is the most common pigment.

B. NUCLEUS.

The nucleus is usually a spherical body. It is delimited from the cytoplasm by a nuclear membrane.

1. DIFFERENTIATED SUBSTANCES OF THE NUCLEOPLASM:
   a. NUCLEAR SAP. A fluid ground substance which fills the nucleus.
   b. NUCLEOLUS. Some nuclei contain nucleoli. These are, typically, small spherical bodies. More than one nucleolus may be present.
   c. CHROMOSOMES. These are Feulgen-positive bodies of characteristic size and shape, which are most conspicuous during cell division. A discussion of the minute structure of the chromosome is beyond the scope of this book.

Cell Division

Reproduction, growth, and repair of tissues depend on some form of cell multiplication. Cells are reproduced by a process of division.

A. AMITOSIS (DIRECT CELL DIVISION).

This is considered a rare method of cell division. It is generally thought to occur only in pathological, senescent, and certain highly specialized tissues.

1. IN AMITOSIS, the nucleus of a "*resting*" (*interphase*) *cell* merely constricts in the middle and finally separates into halves. Fission of the cytoplasm may follow soon after the division of the nucleus.

B. MITOSIS (INDIRECT CELL DIVISION).

The reproduction of most cells involves a series of processes of considerable complexity. Four stages are usually described:

1. PROPHASE. This stage is characterized by a series of changes through which the very fine threads of the "resting" cell are changed in form to the thicker and more conspicuous chromosomes of the metaphase.
   a. Simultaneously with the development of the chromosomes, the centrioles move to opposite sides of the nucleus.
   b. The formation of rays around each centriole results in the development of a structure known as the aster.
   c. Threads form which reach from the chromosomes to the asters. These threads are called spindle fibers.
   d. Threads that reach from one aster to the other are termed *continuous* spindle fibers.
2. METAPHASE. The diagnostic feature of this stage is that the longitudinally split chromosomes are located in the equatorial plane or middle of the mitotic figure.

3. ANAPHASE. This is the period in which the two sets of chromosomes resulting from longitudinal splitting move to their respective asters.
4. TELOPHASE. The two groups of chromosomes now in the vicinity of the asters are reconstructed into the nuclei of typical "resting" cells. A division of the cytoplasm takes place to form the daughter cells. The nucleolus which disappeared during the process of mitosis is reformed, and the spindle fibers gradually disappear.

3

Epithelial Tissues

The epithelial tissues described in this chapter are those having one surface bordering a space or a cavity and the other surface usually adjoining an underlying basement membrane. This latter structure is often so thin as to be imperceptible in routine preparations.

(Epithelial cells may also be arranged in the form of solid cords or masses, parathyroids; in the form of follicles, thyroid glands; or in indefinite arrangements, thymus; but these will be considered in subsequent chapters under the histology of organs.)

In the tissues described here, *only a small amount of intercellular substance is present. Cell outlines are usually indistinct.* Cells are arranged in a single layer (simple) or in several layers (stratified). See illustration on p. 21. Identification is based largely on the shape of the cells in profile view. The free surfaces of the cells may be ciliated or nonciliated.

A. SIMPLE (SINGLE-LAYERED) EPITHELIA.

1. SQUAMOUS. *Examples:* nonciliated—tympanic cavity; posterior epithelium of the cornea, lining of blood vessels and heart (endothelium); lining of peritoneal, pleural, and pericardial cavities (mesothelium); and portions of uriniferous tubules and rete testes.
   a. In profile view, *cells appear as thin plates of protoplasm; their mid portion, where the nucleus is located, forming a prominent bulge on the free surface.*
   b. Usually with one free flat surface.
2. CUBOIDAL. *Examples:* nonciliated—certain follicular cells of ovary, thyroid follicular cells, and kidney tubules; ciliated—mouse uterus.
   a. Nuclei and cell membranes approximately equidistant.
   b. In vertical section the cells are nearly square.
3. COLUMNAR. *Examples:* nonciliated—intestine; ciliated—oviduct:
   a. Tall prismatic cells, *in vertical sections basal nuclei crowded and at practically the same level.* Compare with cuboidal.
   b. Striated cuticular border with terminal bars. *Example:* intestine.
4. PSEUDOSTRATIFIED. *Examples:* nonciliated—male urethra and excretory duct of parotid; ciliated—trachea and large bronchi.
   a. *Two to four layers of nuclei which give a stratified appearance.*
   b. *Nuclei occupy approximately two-thirds of the epithelial layer.* Compare with stratified columnar epithelium.

c. Surface cells are columnar and always touch the basement membrane of the epithelial sheet. Basal cells which are not columnar do not extend to the free surface.
d. Usually ciliated.
e. Vertical sections of pseudostratified epithelium and tangential sections of simple columnar epithelium are easily confused. However, in pseudostratified the nuclei are of several types, those at the base of the tissue are small and dark, those nearer the surface, larger and paler. In the tangential section of columnar epithelium, although nuclei may appear at different levels, they are all of one type.

B. STRATIFIED (MANY-LAYERED) EPITHELIA.

These are characterized by two or more layers of cells. *The kind of stratified epithelium is determined by the shape of the cells in the outer layer or free surface.*

1. SQUAMOUS. *Examples:* cornea, part of the conjunctiva, epidermis of skin, mouth, esophagus, vagina, and part of the female urethra.
   a. *Surface cells usually flat or scale like.* They differ from the cells of simple squamous epithelium in that they possess flat nuclei which do not produce an enlargement of the cell.
   b. *Often with papillated lower border.*
   c. Sometimes a transition from basophilic to acidophilic staining capacity from the base of the epithelial sheet to its surface.
   d. *Basal nuclear layer pronounced.*
   e. Cell membranes may be distinct or indistinct.
   f. *Examples:*
      (1) Corneal epithelium.
         (a) Four to six layers of cells, nonpapillated.
         (b) *Only stratified squamous epithelium without connective-tissue papillae.*
      (2) Skin epithelium.
         (a) Tall papillae of connective tissue penetrate the epithelial layer. Considered in the order from without inward the layers are: corneum, lucidum, granulosum, and germinativum.
         (b) Thin skin shows only the stratum germinativum and stratum corneum clearly.
2. TRANSITIONAL. *Examples:* pelvis of kidney, ureter, bladder, and prostate portion of male urethra. This epithelium is limited in distribution to the urinary tract.

a. The cells at the free surface of transitional epithelium are described by some authors as pear- or balloon-shaped, but by others as somewhat flattened or broadly cuboidal. Actually the same section may show both balloon-shaped and broadly cuboidal cells next to the lumen. This condition appears to be due to the fact that the broadly cuboidal cells at the free surface rest on a layer of balloon-shaped cells, and that there is considerable desquamation of the surface cells *leaving the balloon-shaped cells at the free margin* in certain areas. The frequency with which the superficial cells are found in urine is an indication of the extent to which desquamation of these cells takes place.

b. *Concave facets on the under surface of the surface cells are diagnostic in clinical examinations of urine.*

c. Surface cells are thicker than superficial scaly cells of stratified squamous epithelium.

d. *Nuclei of surface cells tend to be more spherical than in stratified squamous epithelium.* This description applies to collapsed transitional epithelium. When this epithelium is stretched the cells become much flattened.

e. Relatively smaller number of cell layers than in stratified squamous epithelium—*transitional usually not more than two to eight cells deep.*

f. Practically no formation of keratin in transitional epithelium.

g. *Nonpapillated,* hence basal line usually more regular.

3. COLUMNAR. *Example:* part of larynx.

a. Relatively rare type of epithelium.

b. *Outer cells always columnar; inner cells may appear cuboidal.*

c. *Nuclear portion comprises three-fourths to four-fifths of the entire epithelial layer.* Compare with pseudostratified epithelium.

d. Numerous nuclei, compact and ovoid.

e. Basal nuclei form a more nearly straight row as contrasted with the irregular arrangement in pseudostratified epithelium.

f. Goblet cells may or may not be present.

g. Mucosa not papillated.

C. GLANDULAR EPITHELIA.

1. UNICELLULAR GLANDS.

a. GOBLET CELLS. *Example:* intestine.

2. MULTICELLULAR GLANDS.

a. MUCOUS CELLS. *Examples:* sublingual and submaxillary glands.

(1) Large triangular cells with nuclei sometimes flattened and near basement membrane. Alveoli with small but definite lumen.

(2) *Cytoplasm, staining poorly with hematoxylin, is pale slate blue or colorless.*

b. SEROUS (ALBUMINOUS) CELLS. *Example:* parotid gland.

(1) Smaller than mucous cells. Slightly eccentric spherical nucleus, although it varies with secretory cycle. Practically no visible lumen in alveoli.

(2) *Cytoplasm granular* and more or less basophilic. Appearance differs with secretory cycle. Basal striations may be present.

c. SEROMUCOUS (MIXED) GLANDS. *Examples:* submaxillary and sublingual glands. Because they contain both mucous and serous cells these are known as seromucous (mixed) glands.

(1) The intrinsic part of the mixed alveolus usually consists of mucous cells. But attached to the alveolus, at the point farthest away from the intercalated duct, is a thin biconcave cap of serous cells. These cells form the crescent of Giannuzzi (demilunes).

d. Glands which are neither mucous nor serous. *Examples:* liver and kidney. They do not constitute a group united by similarities of structure or function. They are mentioned here merely to point out that many glands exist which cannot be classified as either serous or mucous. Because they are so varied they will be discussed individually in later chapters.

D. PIGMENTED EPITHELIA. *Example:* external epithelium of retina, ciliary body, and to some degree the basal layer of the stratum germinativum.

1. Cells containing large quantities of pigment granules.

E. NEURO-EPITHELIA. *Examples:* taste buds of tongue, olfactory epithelium, auditory sense cells, and rods and cones of the retina. Various localized sensory regions in epithelium consisting of cells of special types not represented in the above mentioned distribution of neuro-epithelia.

Classification of Epithelial Tissues with Their Origin and Location

SIMPLE EPITHELIUM

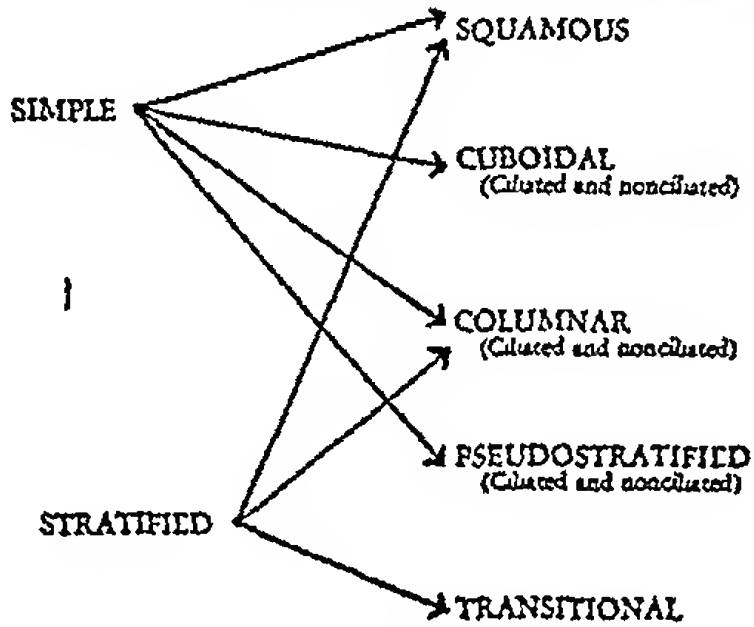
Kind	*Ectoderm*	*Mesoderm*	*Entoderm*
Squamous	Membranous labyrinth. Amnion and chorion	Posterior epithelium of cornea. Rete testis Henle's loop of kidney	Tympanic cavity. Mastoid cells
Cuboidal:			
a. Nonciliated	Anterior surface of lens. Covering of iris and ciliary body. Choroid plexus. Pigmented epithelium of retina. Membranous labyrinth (external spiral sulcus)	Follicular cells of ovary. Collecting tubules of kidney	Smallest bronchioles. Small bile ducts. Small pancreatic ducts
b. Ciliated		Part of uriniferous tubule in the mouse	
Columnar:			
a. Nonciliated	Organ of Corti. Taste buds Ducts of salivary glands	Part of collecting ducts of kidney	Alimentary canal (stomach to anus). Gall bladder
b Ciliated	Embryonic ependyma of brain and of cord	Uterus Oviduct	Bronchioles
Pseudostratified:			
a. Nonciliated		Part of ductus deferens	
b Ciliated	Respiratory part of nasal cavity		Trachea Bronchi. Part of larynx. Eustachian tube

Classification of Epithelial Tissues with Their Origin and Location.—(*Continued*)

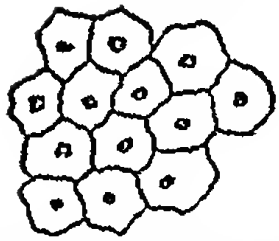
STRATIFIED EPITHELIUM

Kind	*Ectoderm*	*Mesoderm*	*Entoderm*
Squamous	Epidermis. Lips. Ocular conjunctiva. Anal canal. Oral cavity External nares. External auditory tubes. Tear ducts Fossa navicularis of urethra. Vulva	Vagina. Part of cervix	Pharynx. Esophagus. Part of larynx. Vocal cords. Part of epiglottis
Columnar: a. Nonciliated	Palpebral conjunctiva Cavernous urethra. Olfactory membrane	Part of ductus deferens	Part of larynx
b. Ciliated	Respiratory part of nasal cavity		Part of auditory tube Part of larynx
Transitional		Pelvis of kidney. Ureter. Part of bladder	Part of bladder Part of urethra

Word Diagram Summarizing Types of Epithelial Tissues

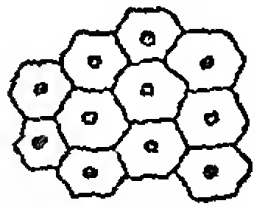


Diagrams of Types of Epithelial Tissues



SIMPLE SQUAMOUS—Surface view

SIMPLE SQUAMOUS—Profile

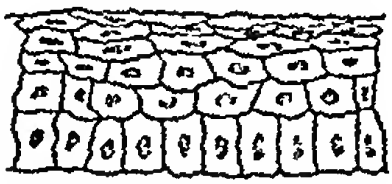


CUBOIDAL OR COLUMNAR—Surface view

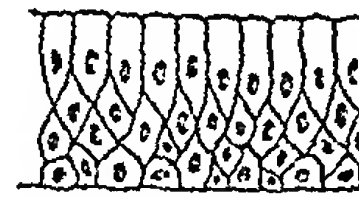
SIMPLE CUBOIDAL—Profile

SIMPLE COLUMNAR—Profile
(Left side with cuticular border, right side ciliated)

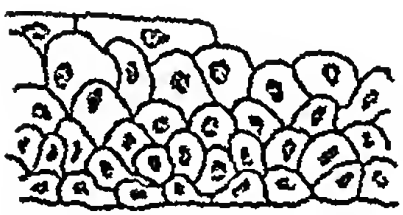
PSEUDOSTRATIFIED
(Ciliated)



STRATIFIED SQUAMOUS



STRATIFIED COLUMNAR



TRANSITIONAL—Collapsed
(Showing two types of surface cells)

TRANSITIONAL—Stretched

4

Connective Tissues

Connective tissues are characterized primarily by the paucity of cells and the dominance of variable amounts and numerous types of intercellular substances, such as fluid, mucus, fibers, cartilage, and bone; therefore they are *identified by the nature of the intercellular material.*

Most connective tissues originate from the same type of mesodermal tissue, the mesenchyme. But, a special condition is found both in the nervous system where the supporting tissue, the neuroglia, is in part derived from the ectoderm, and in the thymus where the reticulum is derived from the entoderm.

Classification is difficult as various types of adult tissues are not sharply separated from one another, so any attempt to classify these tissues into many distinct categories is certain to be artificial. Therefore this classification is very general.

A. MESENCHYME (MESENCHYMA). *Example:* in early embryo. Packing material between the external and internal epithelial layers of an embryo.

1. Consists of loosely arranged stellate cells which form a network with pronounced intercellular spaces variable in size.
2. In fixed preparations the cytoplasm is scanty; a large nucleus appears to occupy most of the cell.
3. The cell membranes are indistinct.
4. Spaces between the cells are filled with an almost fluid substance in living tissue.

   NOTE: The terminology of this primitive type of connective tissue is not well standardized, therefore some authors use the term mesenchyme synonymously with embryonal or mucous; others use the terms embryonic and embryonal synonymously; and still others use mesenchyme and embryonic synonymously. This multiplicity of terminology is likely to prove confusing to a beginning student of histology, and this statement is made in the hope that it will help resolve the difficulty.

B. MUCOUS TISSUE. *Examples:* umbilical cord, and vitreous humor of the eye.

1. Intercellular spaces filled with mucoid substance.
2. Nuclei oval or elongated to conform with the shape of the cell.

3. Borders of the stellate or spindle-shaped cells are indistinct.
4. *A few white fibers eosinophilic.*
5. Some of the fibers are single, while others unite to form wavy bundles.
6. *Example:* umbilical cord.
   a. Periphery covered with flattened epithelial cells.
   b. Intercellular spaces filled with large amount of mucous substance, Wharton's jelly.
   c. Interior may show one vein and two arteries with much muscle in the vessel walls.
   d. The older the cord, the larger the cross-section; and the more fibers occurring, the fewer the cells present.
   e. If the section is taken from a part of the cord near the body of the embryo, the yolk sac may be present. This may prove very confusing to a beginning histologist.

C. NOTOCHORDAL TISSUE. *Examples:* notochord of chick embryo, nucleus pulposus, and a persistent remnant in midpoint of clivus blumenbachii of man. Also in tail of mouse, rat, and salamander.

1. In a four-day chick or 150-mm. pig embryo the syncytial network resembles mesenchymal tissue. *See illustration on p. 35.*
2. The syncytium contains many mucin-filled spaces.
3. In the adult pig the syncytium has become divided into groups of vacuolated cells embedded in a gelatinous matrix.

D. RETICULAR TISSUE. *Examples:* framework of bone marrow, liver, lymph nodes, spleen, thymus, and other lymphoid tissues.

1. Characterized by a cellular reticulum as well as *argyrophylic fibers which branch and anastomose to form diffuse networks.* These fibers may be clearly demonstrated with silver nitrate. The details of the reticular cells, however, cannot be observed in such preparations.
2. *The spaces of the reticular network are filled for the most part with lymph and lymphocytes.*
3. Reticular cells may be in close relation to the fibers of the reticulum.

E. ELASTIC (YELLOW) TISSUE. *Example:* ligamentum nuchae, and fenestrated membrane.

1. Living fibers are yellow in color and elastic in the common sense of the word.

2. *Each fiber is a structureless homogeneous thread.*
3. Fibers branch and anastomose.
4. *Example:* ligamentum nuchae.
   a. Large eosinophilic fibers that curl at the ends.
   b. *Fibers are dense,* running mainly in one direction.
   c. *No nuclei in fibers, but nuclei between fibers rather than between fiber bundles as in tendon.*

F. COLLAGENOUS (WHITE FIBROUS) TISSUE. *Example:* tendons, ligaments, and aponeuroses.

1. Living fibers are white and not so elastic as the yellow fibers.
2. Unlike the yellow fibers, each is composed of extremely minute fibrils, bound together to form a fiber bundle.
3. Fibers wavy.
4. Tendon is a type of dense collagenous tissue:
   a. *Parallel strands of dense white fibrous tissue, frequently wavy.* They appear almost homogeneous.
   b. *Nuclei between fiber bundles or fibers.*
   c. Transverse sections may show winged cells.

G. ADIPOSE TISSUE. *Examples:* outer part of capsule of kidney, in the omentum, and in adult mesentery. *Peculiar because its bulk consists of cells instead of intercellular substance.*

1. *"Signet ring" cells may be present,* i.e., cells with the nucleus pushed to one side.
2. *Cells appear vacuolated because the intracellular fat substance is removed in preparation.*
3. *Nuclei not observed in every cell.*
4. Groups of cells separated by connective tissue (areolar).

H. AREOLAR TISSUE. *Example:* fascia.

1. Yellow elastic fibers, white fibrous fibrils, and bundles of fibers, which are cut transversely, obliquely, and longitudinally, are intermingled in transverse section.
2. Somewhat acidophilic.
3. With hematoxylin and eosin stain, it is difficult to distinguish between elastic and white fibrous fibers.
4. *No apparent arrangement of tissue.*

5. Scattered connective tissue, plasma, and adipose cells.

NOTE: Areolar is classified sometimes as dense and sometimes as loose, the essential difference being that in the former the fiber bundles are closer together than in the latter in which large interspaces are filled with fat cells.

I. CARTILAGE (GRISTLE).

1. PRECARTILAGE. *Example:* embryonic digit.
   a. No matrix, or matrix reduced to a minimum.
   b. Cells small and very numerous.
2. HYALINE CARTILAGE. *Example:* tracheal rings.
   a. *Like ground glass in appearance,* with slightly basophilic matrix. No specific fibers ordinarily seen.
   b. Each cell inclosed within a *small space* (*lacuna*) which during life it completely fills. In mature cartilage there may be as many as four cells in a lacuna. Cells with prominent nuclei and clear cytoplasm.
   c. Much more matrix than in precartilage.
   d. Covered by perichondrium except over the articular surfaces of bone.
3. ELASTIC CARTILAGE. *Examples:* external ear, Eustachian tube, epiglottis, and in some of the laryngeal cartilages.
   a. *Similar to hyaline cartilage, plus a large number of branching yellow fibers between the lacunae.*
   b. Staining of intercellular substance surrounding the capsule is dense compared with hyaline cartilage.
   c. Often distinctly eosinophilic.
   d. Capsules and cells more or less prominent.
   e. Cells likely to form in smaller groups than in hyaline cartilage.
4. WHITE FIBROCARTILAGE (Fibrous Cartilage). *Example:* intervertebral disk.
   a. Differs in appearance from dense white fibrous tissue, such as ligaments and tendons, in that *the meshes of the dense fibrous tissue are permeated by cartilage cells.*
   b. *The cells are usually widely separated and arranged in rows, but differ from tendon cells in their ovoid shape and in the presence of cartilage capsules.*
   c. Capsules small and not well differentiated.
   d. Immediate pericapsular territories are usually free from collagenous fibers.

e. *The fiber bundles, which are slightly acidophilic, run a wavy course through the matrix.* Fibers usually run parallel with one another.

f. Plates of fibrocartilage are not surrounded by a perichondrium.

5. ARTICULAR CARTILAGE. *Example:* covering of the articular surface of the bones.

a. *Usually hyaline cartilage without perichondrium and with cells near one surface greatly flattened.* Other cartilage cells in short columnar groups. Cancellous bone usually found on one side.

J. BONE.

1. CANCELLOUS (SPONGY). *Example:* flat bones of skull and in the epiphysis of long bones.

a. Irregular trabeculae of bone with bone cells, but *without Haversian canals*

b. Blood cells and red bone marrow in the marrow spaces between the trabeculae.

c. Young bone usually shows edge of trabeculae beaded with osteoblasts.

2. COMPACT. *Example:* diaphysis of long bone in cross-section.

a. *Haversian canals surrounded by concentric lamellae of bone.* Haversian canals are channels running longitudinally in the substance of the bone and containing blood vessels, lymphatics and nerves.

b. Interstitial lamellae between Haversian lamellae.

c. Lacunae distinct with canaliculi.

d. Stains pink in decalcified, and bluish in calcified sections.

e. *Periosteum of connective tissue.*

K. DEVELOPMENT OF BONE (OSTEOGENESIS).

1. INTRAMEMBRANOUS OSSIFICATION. *Examples:* Bones of the vault of the cranium, flat bones of face and jaw (membrane bones).

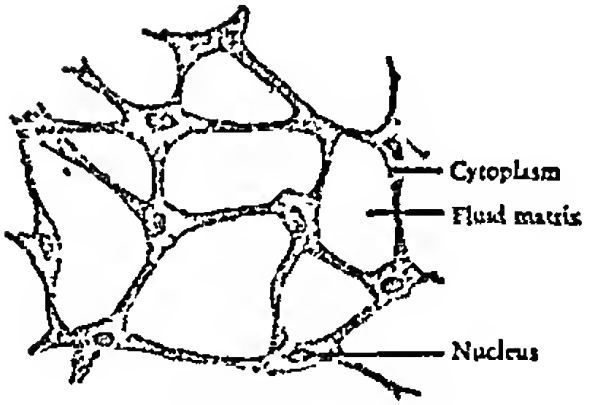
a. Osteoblasts are formed directly from mesenchymal cells. Among the transforming mesenchymal cells appear collagenous *fibrils. Matrix* is deposited on these to form spicules of calcified substances.

b. Adjacent spicules come in contact and fuse with each other to form trabeculae.

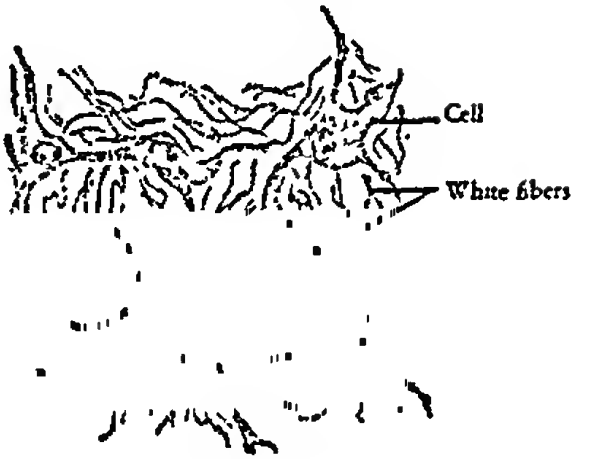
c. Osteocytes become entrapped within the trabeculae to form osteocytes of mature bone.

2. INTRACARTILAGINOUS (ENDOCHONDRAL) OSSIFICATION.
Examples: Shaft of a long bone.
   a. Preëxisting cartilage is replaced by bone. There is cartilage degeneration followed by bone formation.
   b. The essential process of intracartilaginous bone formation is like that which occurs in intramembranous bone.
   c. Fibers are formed and matrix is deposited upon them, thus giving rise to separate spicules which later become confluent, forming a mass of calcified trabeculae.
   d. The difference between the spicules of the two kinds of bone is that in intracartilaginous ossification, each spicule is developed around a fragment of cartilage matrix; while in intramembranous bone spicules, no such substrate is present. The zones which represent different stages of the development of intracartilaginous bone are shown in the illustration of developing bone on p. 35.

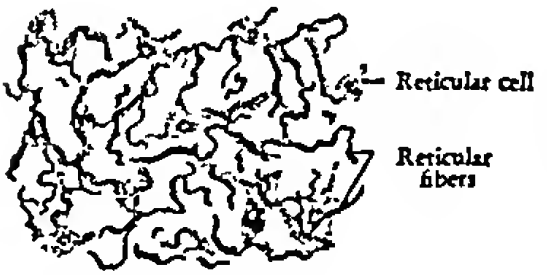
Diagrams of Types of Connective Tissues



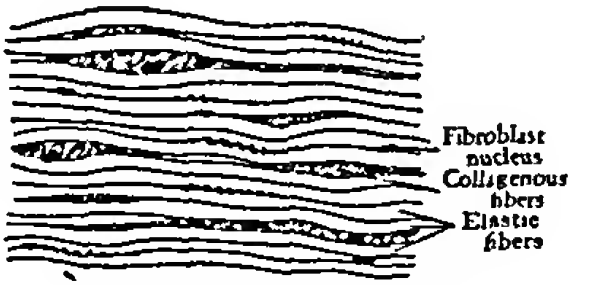
MESENCHYMAL



MUCOUS

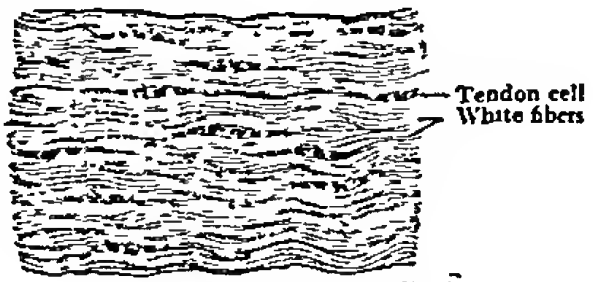


RETICULAR

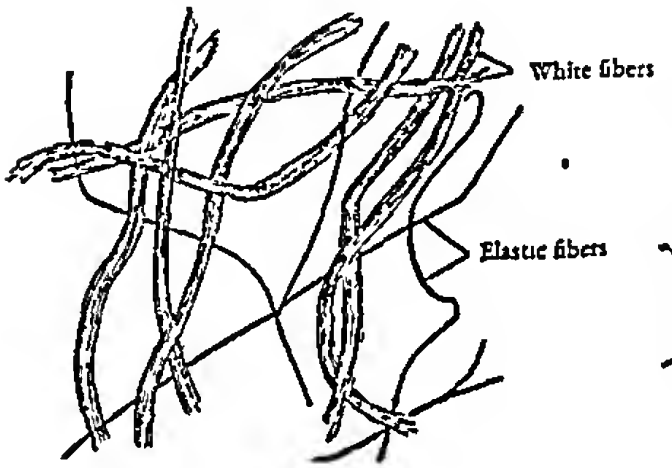


LIGAMENTUM NUCHAE

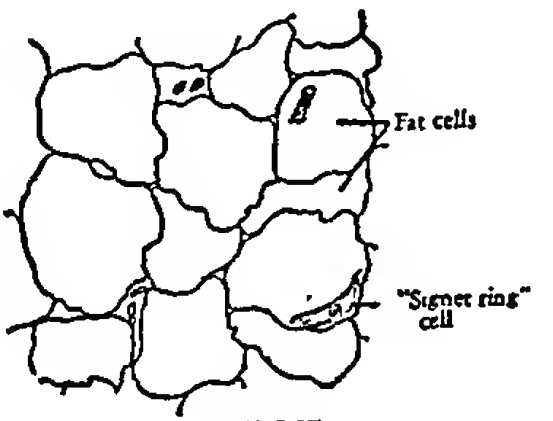
TENDON—Cross-section



TENDON—Longitudinal



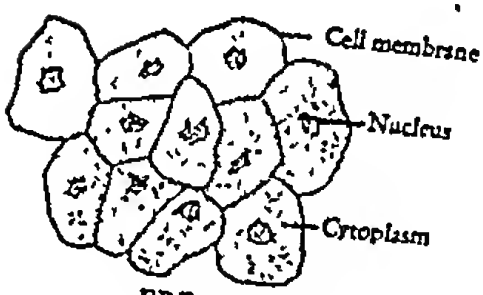
AREOLAR



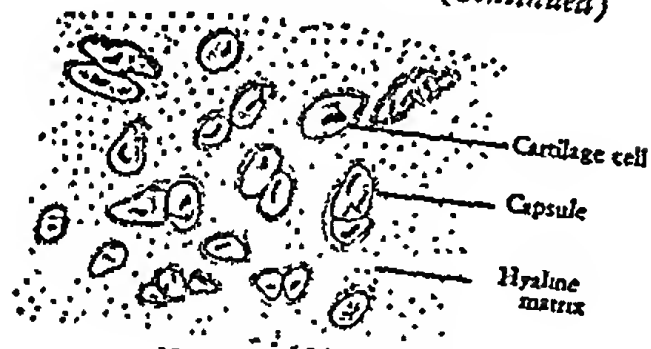
ADIPOSE

CONNECTIVE TISSUES

Dingrams of Types of Connective Tissues.—(*Continued*)

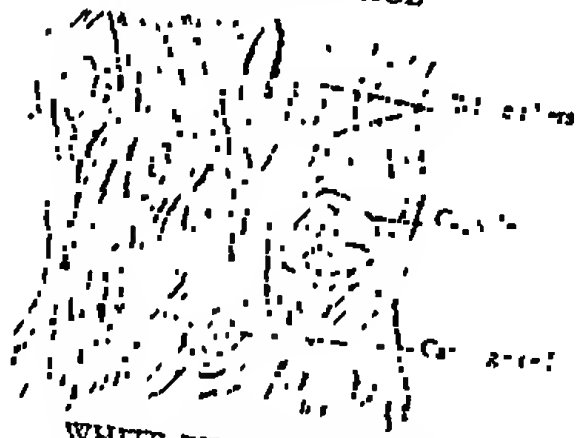


PRECARTILAGE



HYALINE CARTILAGE

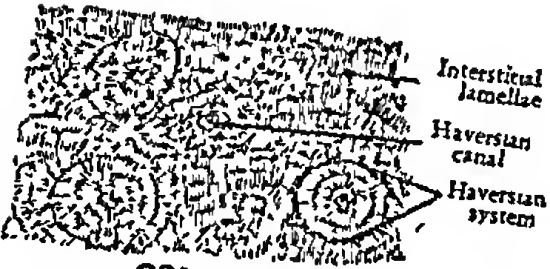
ARTICULAR CARTILAGE



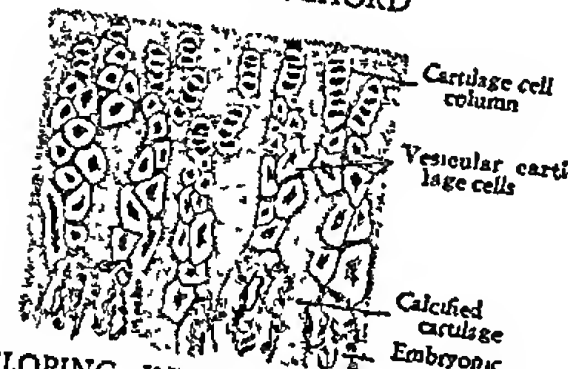
WHITE FIBRO-CARTILAGE

ELASTIC CARTILAGE

NOTOCHORD



COMPACT BONE



DEVELOPING INTRACARTILAGENOUS BONE

5

Human Blood

Blood may be considered as one type of connective tissue, consisting of *free cells (corpuscles)* and a *fluid intercellular substance* (plasma). The mesenchyme of mesodermal origin gives rise to the blood as well as to most of the connective tissues. Thus it is evident that blood is both structurally and genetically related to connective tissue. Functionally, however, it does not fit into the connective-tissue picture, for connective tissue is usually defined as a *medium of support or connection between the various body structures.*

A. RED CORPUSCLES (ERYTHROCYTES, ERYTHROPLASTID OR PLASTID).

1. These are recognized by their pink color,[1] *dark borders, and light central areas which do not contain nuclei.*
2. They are the most numerous of the formed elements in the blood.
   Male, about 5,000,000 per cu. mm.
   Female, about 4,500,000 per cu. mm.
   Average, 7.5 microns in diameter. In a given section, the erythrocytes furnish a useful gauge for estimating the size of other structures.
3. CRENATED CORPUSCLES.
   a. These are shrunken erythrocytes on the surface of which are spine or *knoblike processes.*
4. ROULEAUX.
   a. Refers to the tendency of erythrocytes to pile up like rolls of coins.
5. HEMIN CRYSTALS.
   a. If dry blood is placed on a slide with 5 crystals of common salt (NaCl), the size of a pin head, and both are dissolved in two or three drops of glacial acetic acid, which is then heated until it boils, a product of hemoglobin *is formed, called hemin. Hemin* occurs in deep brownish, rhombic crystals, known as *Teichmann's crystals.* These appear like straws scattered about on the slide.

[1] All colors of blood corpuscles refer to preparations stained with Wrights' blood stain

B. WHITE CORPUSCLES (LEUKOCYTES).

1: These are true cells for they contain nuclei. They may be classified as nongranular and granular. About 8,000 per cu. mm.
Size varies with type.

a. Agranulocytes (cytoplasm without granules).

(1) Lymphocytes.

(a) Cells are slightly to considerably larger in size than erythrocytes, with a relatively large nucleus, about which there may be a narrow rim of slightly basophilic cytoplasm. *In some the cytoplasm is so scanty that only the large spherical nucleus is distinguishable.* The nucleus of large lymphocytes may be located at one side of the cell. Percentage: 20%–25%.[2] Size: 7–10 *microns.*

(2) Monocytes (mononuclear leukocytes).

(a) Cells which are typically larger than lymphocytes, though they cannot always be sharply differentiated from some of the larger lymphocytes. *The typical monocyte has far more cytoplasm than a lymphocyte; and the nucleus, usually eccenteric in position, is round, oval, slightly indented, or crescentic in shape.* The nucleus is paler than the nucleus of a lymphocyte, and the cytoplasm is faintly basophilic with occasional granules. Percentage: 3%–8%. Size: 12–15 microns.

b. Granulocytes (cytoplasm contains granules).

(1) Polymorphonuclear leukocytes. Relatively large cells which are generally much larger than an erythrocyte.

(a) Neutrophils (heterophils).

(*1*) Cells almost twice the size of an erythrocyte. *The nucleus is highly polymorphous and elongated, with a bent or twisted body which consists of several irregular, thin, chromatic threads.* The number of lobes varies from three to five, the most common number being three. The cytoplasm is finely granular and stains a faint lilac color. Percentage: 60%–75%. Size: 9–12 microns.

(b) Eosinophils.

(*1*) Cells about twice the size of an erythrocyte. *The nucleus often has two oval lobes connected by a chromatic thread. The*

[2] All percentages relative to the blood refer to the total number of leukocytes in man.

cytoplasm contains coarse refractive granules which stain a red color. Percentage: 2%–5%. Size: 10–14 microns.

(c) Basophils.

(*1*) Cells which are somewhat larger than an erythrocyte. *The nucleus is usually bent in the form of an S and is provided with two or more constrictions. It is usually centrally placed and stains faintly. The cytoplasm contains very large irregular granules which stain a deep blue color.* These coarse granules often completely obscure the nucleus. Percentage: 0.5%–1%. Size: 8–10 microns.

NOTE: The diameters given for the leukocytes refer to living blood. The size in smears is quite variable but in general a cell is larger in smear preparation due to stretching and flattening.

C. BLOOD PLATELETS.

1. *These bodies in a dry smear usually disintegrate into small groups of basophilic granules when colored with Wright's blood stain.* They are often found adhering to one another in clumps.

Summary of the Formed Elements of Human Blood

	Type of Cell	*Diameter in Microns*	*Nucleus*	*Cytoplasmic Granules Wright's Stain*	*Number per Cubic Millimeter*	*Phagocytic Properties*
	Erythrocytes	About 7.5	None	None	Male, about 5,000,000. Female, about 4,500,000	
LEUKOCYTES	**Lymphocytes**	7–10	Spherical	None	20%–25%	Absent or slight
LEUKOCYTES	**Monocytes** (Mononuclear leukocytes)	12–15	Usually eccentric in position Round, oval, slightly indented, or crescentic in shape	None	3%–8%	Highly phagocytic. Engulf particulate matter
LEUKOCYTES	**Neutrophils** (Heterophils)	9–12	Highly polymorphous. Elongated, bent, or twisted body with three to five lobes connected by thin chromatic threads.	Neutrophilic Stain faint lilac color	60%–75%	Highly phagocytic. Ingest small, discrete particles as cinnabar, carbon, and bacteria
LEUKOCYTES	**Eosinophils**	10–14	Usually two oval lobes connected by a chromatic thread	Coarse, refractive Stain red	2%–5%	Absent or slight
LEUKOCYTES	**Basophils**	8–10	Usually bent in the form of S; provided with two or more constrictions	Large, irregular. Stain deep blue	0 5%–1%	Not known
	Blood Platelets	About 3	None	Basophilic	Average about 200,000 to 300,000	None

6

Muscular Tissue

A. SMOOTH MUSCLE (NONSTRIATED OR INVOLUNTARY MUSCLE). *Examples:* gastrointestinal muscle, muscle of bladder, and uterine muscle.

1. LONGITUDINAL SECTION.
   a. Cytoplasm of the muscle fiber exhibits vague longitudinal markings which in special preparations prove to be longitudinal myofibrils (myofibrillae).
   b. *A single central elongated nucleus within the fiber.*
   c. In many structures in which smooth muscle occurs, the cells are close together and form a more or less definite muscular membrane in which the outlines of the cells may not be distinguishable. *May be confused with connective tissue, from which it is distinguished by the position of the nuclei which are within the fibers.*
   d. With hematoxylin and eosin, the muscle takes a deeper and more purple stain than do connective-tissue fibers, and is not so refractive.
2. CROSS-SECTION.
   a. *The position of the nucleus is in the central portion of the cells.*
   b. *The difference in size and form of cells occurring in the same bundle is due to the fact that the fusiform cells may be cut through the thick central portion or at the narrow ends.*
   c. Cells covered by so thin a membrane that it is imperceptible in ordinary preparations.
   d. *Smooth muscle is less eosinophilic than striated voluntary muscle or cardiac muscle.*
   e. Fibers not grouped in fasciculi but separated by connective tissue.

B. STRIATED MUSCLE (SKELETAL MUSCLE, VOLUNTARY MUSCLE, OR STRIPED MUSCLE). *DESCRIPTION IS FOR HIGHER VERTEBRATES.* *Examples:* tongue muscle, biceps, triceps, and several hundred others.

1. LONGITUDINAL SECTION.
   a. *Parallel, cylindrical, eosinophilic fibers of about the same size.*
   b. Fibers of greater length and diameter than in smooth muscle.
   c. *Cross-striations* (continuous alternate dark and light bands).

d. *Numerous oval nuclei in close relation to sarcolemma.* Nuclei eccentric in position.
e. Interfibrous connective-tissue nuclei present.

2. CROSS-SECTION.
a. Fibers nearly all of the same size, eosinophilic.
b. Myofibrils appear as dots in the fibers.
c. *Nuclei infrequently seen in cross-section, but when present usually appear placed in the "corners" of the fibers.* To be more exact, the nuclei are usually located directly under the cell membrane (sarcolemma). The peripherally placed nuclei constitute the most outstanding feature of transverse sections.
d. Fibers appear rounded or polygonal in outline.
e. Fibers may be grouped in fasciculi with connective tissue between the fasciculi.

C. CARDIAC MUSCLE.

Since the fibers of cardiac muscle lie in various planes, *areas will be found in a single section in which they are cut both longitudinally and transversely.* They are compact in general appearance.

1. LONGITUDINAL SECTION.
a. *Fibers branch and anastomose.*
b. Protoplasm granular and may show pigmentation.
c. *Large oval nuclei, usually near central axis of fibers.*
d. Region surrounding nucleus contains no myofibrils.
e. *Irregular striations closer together and not as clearly visible as in voluntary muscle.*
f. Myofibrils coarser than in skeletal muscle.
g. Myofibrils often show a radial arrangement in cross-section.
h. Intercalated disks are cross bands peculiar to heart muscle. These disks are usually very indistinct in ordinary preparations but may be brought out clearly with special staining technics.

2. CROSS-SECTION.
a. *Nuclei relatively rare, more or less centrally placed in fibers.*
b. No definite fasciculi.
c. *Nuclei larger than in voluntary muscle.*
d. Cut ends of myofibrils are frequently so arranged as to suggest short parallel bands or spokes of a wheel.

7

Nervous Tissue

Nervous tissue is specialized for the reception of stimuli and the transmission of impulses to all parts of the body. This is the most highly specialized tissue in animals. The nervous system consists of the following tissues: nerve cells (neurons), supporting tissue (neuroglia), and the connective tissue proper, including the meninges and the coverings of the nerves.

A. NERVE CELLS (NEURONS).

1. CYTOPLASM. Part surrounding nucleus, sometimes called the perikaryon. In the axon it is termed axoplasm. A variety of technics are necessary to demonstrate the various constituents, therefore several different preparations must be studied to observe the whole cytological picture.
   a. NEUROFIBRILS. Threads which run in every direction and extend into the nerve processes.
   b. CHROMOPHILIC (TIGROID) SUBSTANCE. It consists of granules clumped together to form small masses known as *Nissl* or *tigroid bodies*. These stain deeply with aniline dyes, much like chromatin of the nucleus. Nissl bodies occur in dendrites, but are not present in the axon or at its point of implantation on the cell body (axon hillock).
2. NUCLEUS. It is roughly spherical and relatively large, especially in the motor neurons of the ventral horns of the gray matter of the cord.
3. NERVE PROCESSES. A typical nerve cell has branched processes arising from the cell body. Three distinct types of nerve cells are recognized according to the number of processes which they possess.
   a. UNIPOLAR (MONOPOLAR) CELL. *Example:* dorsal ganglion of a spinal nerve. A single process extends out from the cell body but it soon divides into two branches. One branch corresponds to a *dendrite* (carries impulses toward cell body) and the other is an *axon* (carries impulses away from cell body).
   BIPOLAR CELL. *Examples:* Purkinje cells of the cerebellum, retina, and ganglia of inner ear. Two processes, one is a dendrite and the other an axon.

c. MULTIPOLAR CELL. *Examples:* motor cells from the ventral horn of the spinal cord. Several processes consisting of one axon and a number of dendrites.

B. MYELINATED (MEDULLATED) NERVE FIBERS.

1. LONGITUDINAL SECTION.
   a. PARALLEL FIBERS, usually stain lightly.
   b. Irregular diameter of fibers gives it the general appearance of being wavy.
   c. NEURILEMMA CELLS. Nuclei oval, finely granular.
   d. FIBROBLASTS (FIBROCYTES). Nuclei thin, flattened, and dark-staining.
   e. *Central axis cylinder visible, composed of small delicate threads (neurofibrils).*
2. CROSS-SECTION.
   a. *Irregular small circles (the neurilemma) of different sizes, each with a dark deeply stained dot (the axis cylinder).*
   b. The interval between the axis cylinder and the neurilemma (sheath of Schwann) corresponds to the space occupied by the myelin.
   c. In preparations stained only with osmic acid, the myelin sheaths appear as black rings enclosing the unstained axis cylinders.
   d. There are three connective-tissue sheaths which may be observed in a transverse section of a large nerve trunk.
      (1) Epineurium. Outermost connective-tissue sheath surrounding several fasciculi.
      (2) Perineurium. Sheath around each individual fasciculus.
      (3) Endoneurium. Prolongations of the perineurium extend as septa into the large nerve bundles and may penetrate between individual nerve fibers.

C. UNMYELINATED (NONMEDULLATED) NERVE FIBERS OR REMAK'S FIBERS.

Example: these nerves may be found between the circular and longitudinal layers of smooth muscle in any part of the digestive tube.

1. Axis cylinders composed of neurofibrils.
2. Axis cylinder usually covered by a delicate neurilemma.
3. Viewed in cross-section, the unmyelinated fibers appear as small discrete dots, which remain distinct with changing focus. In longitudinal sections, they look like fine parallel lines. Obliquely cut, they are difficult to recognize.

4. *Their diameter is small, sometimes less than 1 micron.*
5. Compared with medullated fibers, they are very inconspicuous.

D. SPINAL AND CRANIAL GANGLIA.

1. *Cells appear round and granular and are larger than those of the autonomic ganglia.*
2. Nuclei are vesicular and may contain prominent nucleoli.
3. *Large bundles of nerve fibers may isolate cells into groups.*
4. *Large bundles of myelinated nerve fibers traverse the ganglion.*

E. AUTONOMIC (THORACICOLUMBAR AND CRANIOSACRAL) GANGLIA.

1. *Cell bodies are usually smaller than those of the spinal ganglia.*
2. *No definite grouping of cells in the autonomic ganglia.*
3. Capsule is less distinct and contains less satellite cells than does the capsule of a spinal ganglion cell.
4. Autonomic ganglia do not show the regular arrangement of large bundles of myelinated fibers traversing the ganglion.
5. *Chiefly nonmedullated fibers lining the ganglion.*

F. MOTOR NERVE ENDINGS. Special staining technics are required to demonstrate these structures.

1. MOTOR NERVE ENDINGS OF STRIATED MUSCLES
   a. *Nerves end in motor end plates.*
   b. Each nerve just before ending becomes much branched so as to innervate from 10–20 muscle fibers.
2. *MOTOR NERVE ENDINGS OF SMOOTH AND CARDIAC* MUSCLES.
   a. Nerve terminations more simple than in striated muscle.
   b. Repeated branching forms a *primary plexus*, which surrounds the muscle bundles.
   c. Axis cylinder fibers from primary plexus may penetrate the smooth muscle of cardiac muscle to form a delicate *secondary plexus*, from which short branches pass to end in minute dilations or granules upon or in the muscle cells.

G. SENSORY NERVE ENDINGS (TELODENDRIA OR DENDRITES). These endings are essentially terminal dendrites as distin-

guished from the motor end plates which are terminal axons. The sensory endings form *telodendria*, or end brushes, which vary in structure.

1. NONENCAPSULATED ENDINGS.
   a. Free endings are the simplest type and occur in epithelium, connective tissue, muscle, and serous membranes. The branches end in granules, varicosities, or minute granules.
   b. FUNCTION: pain and temperature.
2. *ENCAPSULATED ENDINGS.*
   a. MERKEL'S CORPUSCLE (CORPUSCLE OF GRANDRY). *Examples:* deep layers of epithelium of the skin, external root sheath of hair, and various other places. *Skin of duck's bill best material for study.*
      (1) Consists of a *modified epithelial cell* (*tactile cell*) and of a terminal widening of the axis cylinder, the *tactile disk.*
      (2) Tactile in function.
   b. PACINIAN CORPUSCLE (CORPUSCLES OF VATER-PACINI, LAMELLAR CORPUSCLES). *Examples:* penis, clitoris, nipple, mammary gland, conjunctiva, cornea, heart, mesentery, pancreas, deeper subcutaneous connective tissue, and in loose connective tissue generally.
      (1) Elliptical in shape. Often as large as a pin head and is easily seen by the unaided eye.
      (2) *Inner bulb (core) surrounded by lamellae of connective tissue. In cross-section, the lamellae look like the concentric rings in a freshly cut tree trunk.*
      (3) The inner bulb contains the axis cylinder.
      (4) Function: deep or heavy pressure sense.
   c. TOUCH CORPUSCLES OF MEISSNER (TACTILE CORPUSCLES). *Example:* in cutaneous papillae of finger tips.
      (1) *Corpuscle has peculiar spirally striated appearance.*
      (2) Within corpuscle, nerve fibers break into a plexus of varicose fibers, many of which end in knobbed extremities.
      (3) Corpuscles also contain numerous flattened or cuneiform epithelioid cells.
      (4) Corpuscles surrounded by connective-tissue capsule.
   d. MUSCLE SPINDLES (NEUROMUSCULAR SPINDLES OR BUNDLES).
      (1) Groups of poorly differentiated muscle fibers enclosed within a connective-tissue sheath.

(2) The sheath is perforated by one or more sensory nerve fibers which end around the muscle fibers.

(3) The muscle fibers of the spindle are thinner than ordinary fibers. They also contain more nuclei, especially in the regions surrounded by nerve fibers.

(4) Identification of neuromuscular spindles is of special importance to pathologists, since they persist after all contractile elements have undergone atrophy or have been replaced by adipose tissue. Hence, the muscle spindles provide a valuable means of recognizing a region of muscle tissue under extreme pathological conditions.

(5) Function: receive stimuli of position and movement.

e. MUSCLE-TENDON SPINDLES (ORGANS OF GOLGI).

(1) Located at junction of muscle with tendon.

(2) The spindle consists of tendon bundles usually covered by a thin capsule.

(3) One or several afferent nerve fibers enter the spindle, where they break into complicated arborizations.

(4) Function: receive stimuli of position and movement.

H. NEUROGLIA ("GLIA"). This constitutes the supporting tissue of the central nervous system, of the retina, and of the capsular cells of the peripheral ganglia. The neuroglia cells, though supportive in function, are usually considered with the conductive elements of the nervous system. Cytoplasm and processes can be seen only by special histological technics.

1. ASTROCYTES FROM ECTODERM.

a. Cells have large oval nuclei, granular cytoplasm, and branching granular protoplasmic processes. Some of the processes end in "*sucker feet*" or *pedicles*. *Spiderlike*. Possess *gliosomes* which are slightly elongated granules in the cytoplasm.

2. OLIGODENDROGLIA (OLIGODENDROCYTES) FROM ECTODERM.

a. Cells and nuclei small. Processes are *fine and few as compared with astrocytes*. *Gliosomes present*.

3. *MICROGLIA FROM MESODERM*.

a. Very small, elongated cell bodies with deeply staining nuclei, *beset with spines*. *No gliosomes present*.

4. EPENDYMA.
   a. Closely packed columnar epithelial cells lying in the thick walled portions of the neural cavities.
   b. The axes of the cells are perpendicular to the central canal and ventricles.
   c. The cells may have cilia or flagella which protrude into the neural cavity in certain forms and in certain places.

I. SPINAL CORD.

1. *Composed of a central column of gray matter which is roughly H-shaped in cross-section.* Motor nerve cells are grouped in the larger lobes of the "H," which are termed the ventral or anterior horns. In center of cord is ependyma-lined central canal.
2. *White matter surrounding the gray matter is composed of transversely cut nerve fibers of ascending and descending tracts.*
3. Surface may show pia, a thin connective-tissue layer with blood vessels. The cerebrum may also show this if the surface is included in the section.

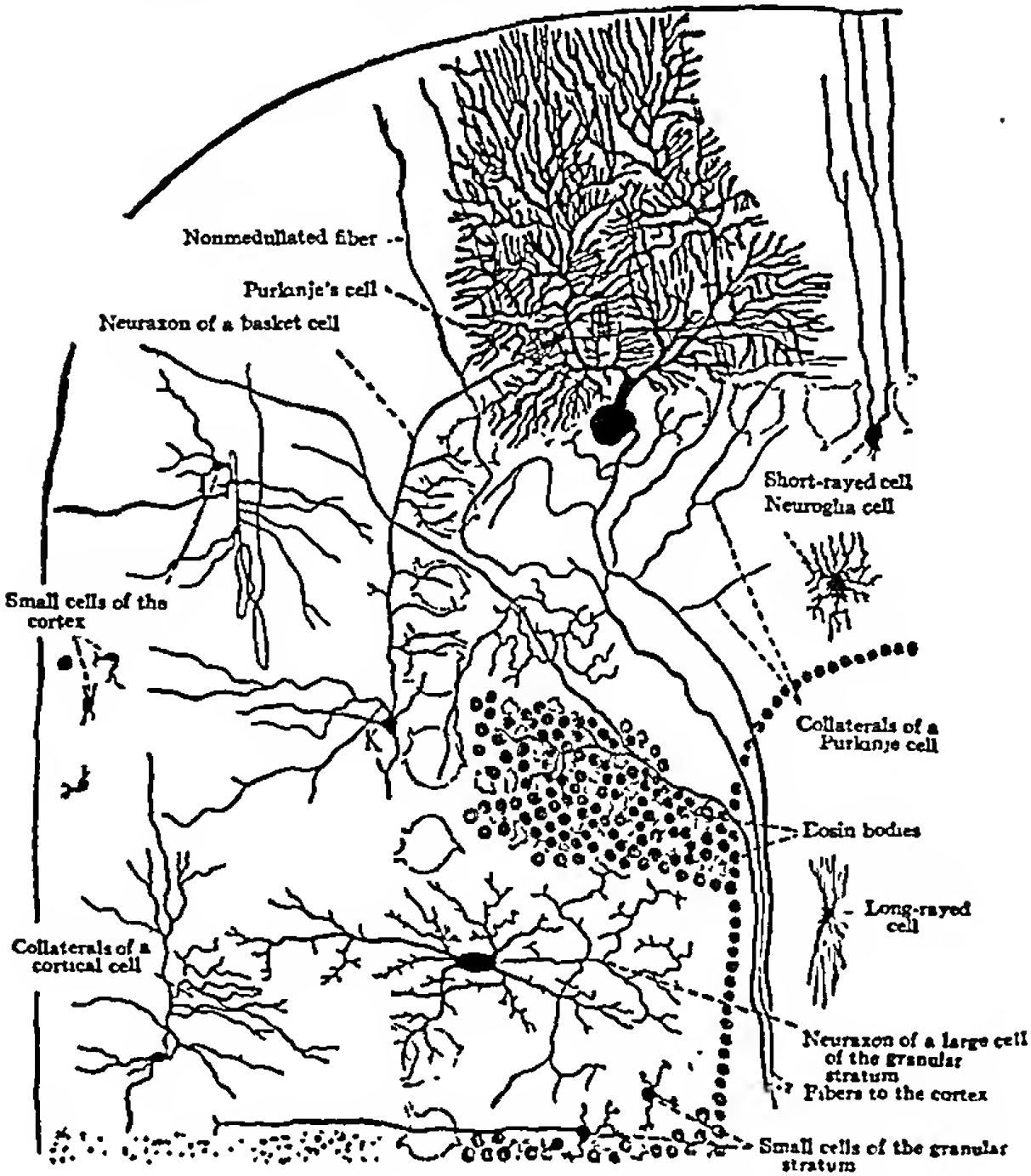
J. CEREBELLUM.

1. The cortex consists of three layers: an inner granular layer composed of small nerve and neuroglia cells; *a middle ganglionic layer composed of Purkinje's (tree-like) cells*, and an outer gray layer composed chiefly of nerve fibers and large and small cortical cells. See diagram of a section of the cerebellum on p. 63.

K. CEREBRUM.

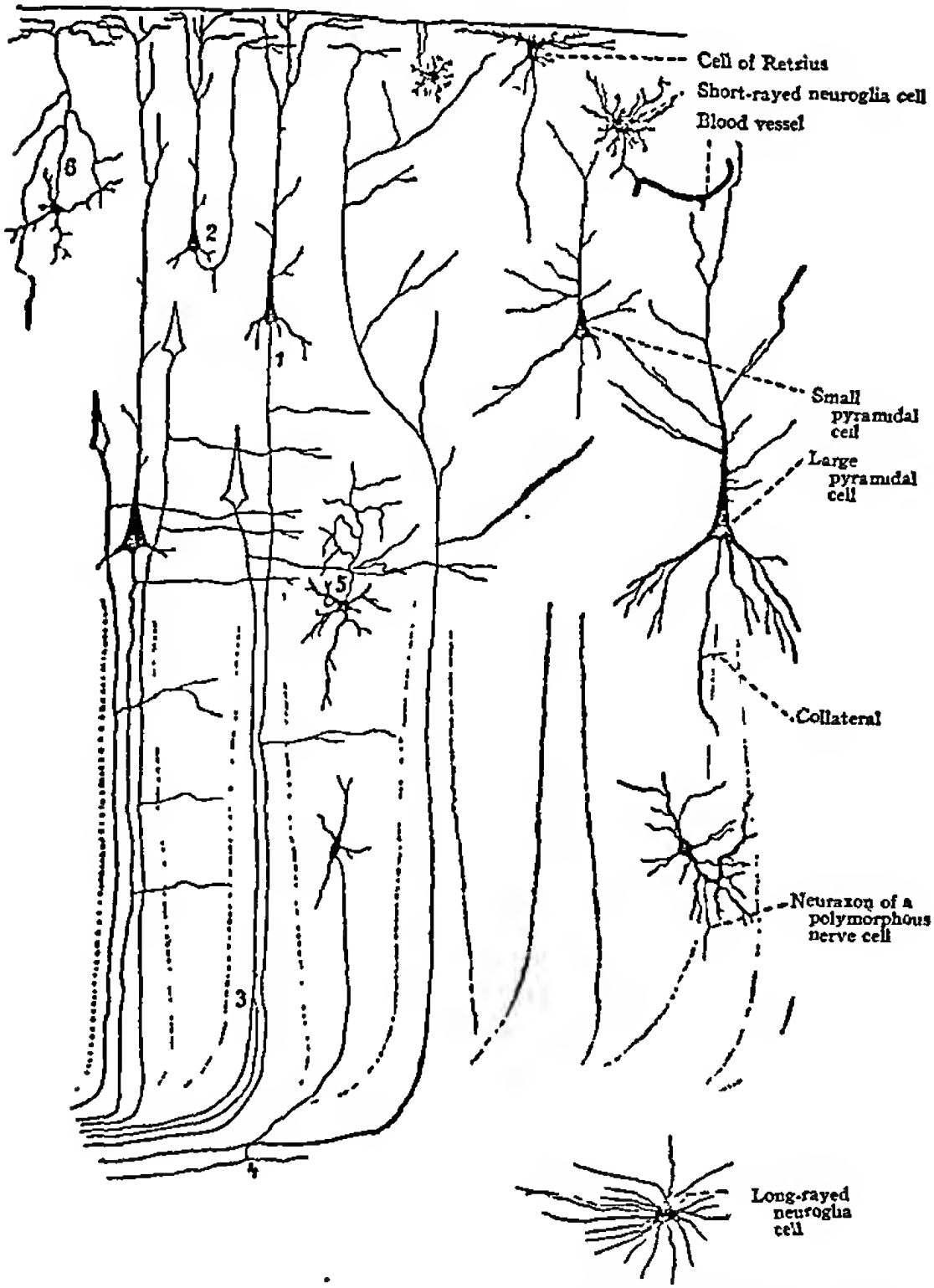
1. Light staining background with many small fibers and a few small round nuclei.
2. *Various sized pyramidal cells, sometimes perineuronal spaces are made conspicuous by shrinkage of the cells.*
3. Different areas of the cortex vary in the number of cell layers, some containing as few as four, others containing as many as eight. The area *illustrated on p. 64* contains four cell layers which are from without inward:
   a. The molecular layer or plexiform layer of Cajal.
   b. The layer of small pyramids.
   c. The layer of large pyramids.
   d. The layer of polymorphous cells.

Diagram of a Sagittal Section of the Cerebellum



All the cells are drawn from Golgi preparations from an adult man, with the exception of the large granule cell, which is from a kitten. K, large cortical or basket cell. (Courtesy, Bremer and Weatherford: "A Text-book of Histology," 6th ed., Philadelphia, The Blakiston Company.)

Diagram of the Cerebral Cortex



The cells on the right are drawn from Golgi preparations of an adult man. × 120 The left portion of the diagram is × 60 (Courtesy, Bremer and Weatherford. "A Text-book of Histology," 6th ed., Philadelphia, The Blakiston Company.)

8

Vascular System

The division of blood vessels into various types is of necessity artificial, for one type of vessel merges into another without marked boundaries. Sometimes arteries of rather small caliber have walls which suggest large arteries, and vice versa. *In general, veins can be distinguished from arteries of the same size by a thinner wall, greater diameter of the lumen, and a collapsed condition.*

A. CAPILLARIES. Vary in diameter from 4.5–12.0 microns.

1. Capillaries are endothelial tubes usually separated from other tissues by a thin connective-tissue layer.

B. SMALL ARTERIES (ARTERIOLES). Arteries with a caliber of 0.3 mm. or less.

1. *Tunica interna (intima)* consists of endothelium and the internal elastic membrane. *The latter is markedly scalloped in sections.*
2. *Tunica media consists of smooth muscle fibers.*
3. *Tunica adventitia (externa)* approximately equals the media in thickness; it is a layer of loose connective tissue with longitudinally orientated, thin, collagenous, and elastic fibers. Small arteries lack a definite external membrane.

C. MEDIUM-SIZED ARTERIES (MUSCULAR TYPE). *Example:* radial artery.

1. Tunica interna (intima) similar to above except that it is thicker. This is due to a layer which consists of a few fibroblasts, thin collagenous bundles, and thin interlacing elastic fibers between the endothelium and the internal elastic membrane.
2. *Tunica media differs from that of arteriole, not only by possessing a thicker muscle layer, but also by possessing thin elastic fibers which appear between the cells as the caliber of the vessel increases.*
3. Tunica adventitia (externa), comparatively *very thick*, and sometimes thicker than the tunica media. An elastic membrane, immediately adjacent to the smooth muscles, stands out well-defined.

D. LARGE-SIZED ARTERIES (ELASTIC TYPE). *Example:* aorta.

1. Tunica interna (intima) is relatively thick. Thin subendothelial layer is bound externally by a fenestrated elastic membrane. Poorly *delimited*

from the tunica media because of the large amount of elastic tissue in the media, forming membranes similar to the internal elastic membrane of the interna.

2. *Tunica media consists mainly of elastic tissue.*
3. Tunica adventitia (externa) is relatively thin. Like the tunica interna, it cannot be sharply distinguished from the media because of the absence of a well-defined, external, elastic membrane which is different from the most external of the elastic membranes of the media. There is a gradual transition from the tunica adventitia into the surrounding, loose, irregularly arranged, connective tissue which contains many fat cells. In the adventitia and outer portion of the media are small blood vessels (vasa vasorum) and nerves (nervi vasorum).

E. ARTERIOVENOUS ANASTOMOSES.

1. In different parts of the body, many arterioles connect directly with venules instead of through capillaries.
2. As an arteriole passes to a venule, the subendothelial elastic tissue disappears and the endothelium lies directly upon the musculature.
3. The whole of the vessel has a thickened adventitia of loose collagenous connective tissue.
4. Arteriovenous anastomoses look more like an arteriole with a thickened wall than a venule.

F. SMALL VEINS.

1. Diameter of about 20 microns.
   a. These consist of a layer of *endothelium surrounded by a very thin layer of connective tissue* composed of longitudinally directed collagenous fibers and fibroblasts.
2. *Diameter of about 45–200 microns:*
   a. Smooth muscle cells appear between endothelium and connective tissue when the diameter increases to about 45 microns. At this diameter the muscle cells are some distance from each other; they later become arranged closer and closer together until a continuous layer is present in veins with a diameter of about 200 microns.
3. Diameter of over 200 microns.
   a. Tunica interna (intima) consists only of endothelium.
   b. Tunica media consists of one or *several layers of smooth muscle cells.*

c. Tunica adventitia consists of scattered fibroblasts and thin elastic and collagenous fibers.

G. *MEDIUM-SIZED VEINS.* Diameter of from 2–9 mm.

1. Tunica interna (intima) has a peculiar endothelium in that its cells, in contrast to the elongated cells of the arteries, are of polygonal form; sometimes an inconspicuous connective-tissue layer is present which contains more or less elastic fibers. Tunica interna is poorly developed in comparison to that of an artery. A distinct boundary between interna and media may not exist.
2. *Tunica media is much thinner than in the arteries.* It consists mainly of circularly arranged, smooth muscle fibers between which are abundant, longitudinal, collagenous fibers.
3. Tunica adventitia (externa) is usually much thicker than the media. It consists of *irregularly arranged connective tissue with rather thick, longitudinal, collagenous bundles,* and elastic network. *Adjacent to the media* there may be some smooth muscle fibers.

H. LARGE-SIZED VEINS.

1. Tunica interna (intima) has same structure as in the medium-sized veins.
2. *Tunica media has varying thicknesses; in general, it is poorly developed and is sometimes absent.* The structure is the same as in veins of medium caliber.
3. *Tunica adventitia (externa) composes the greater part of the venous wall and is usually several times the thickness of the media.* It consists of irregularly arranged connective tissues containing thick elastic fibers, and, mainly, longitudinal collagenous fibers. Adjacent to the media, or to the interna if the former is absent, the adventitia contains very well-developed longitudinal layers of smooth muscles and elastic networks.

I. SINUSOIDS. *Example:* adrenal gland. Diameter of from 5–30 microns.

1. Structurally, the sinusoids differ from capillaries in the following three ways:
   a. *They usually have a larger lumen with irregular tortuous walls.*
   b. Thin endothelial lining may be incomplete.
   c. *There is no distinct connective-tissue layer between the endothelial tube and the tissue cells.*
2. In the adult mammalian body, sinusoids occur in the liver, spleen, hemolymph glands, erectile tissue of male and female genitalia, the medulla of the adrenals, and other places.

J. LYMPHATIC VESSELS.

1. *Lymph vessels are to be distinguished from veins of the same size, not only by their decidedly thinner walls and more collapsed appearance, but also by the absence of red corpuscles in the lumen of the vessel unless extravasation has occurred. On the other hand, lymphocytes are frequently present, together with a granular or fibrous coagulum. The tissue is loosely arranged as compared with that of a vein.*

   Cross-sections of cat intestine, in the phase of fat absorption, stained with Sudan III, give a striking demonstration of lymphatic vessels.
2. Small lymph vessels are difficult to distinguish from interfibrillar tissue spaces because of their collapsed condition. *They may appear as endothelium-lined irregular spaces in the connective tissue.*
3. As the lymphatic vessels become larger they are covered by thin, mainly collagenous bundles, elastic fibers, and a few smooth muscle cells. Those lymphatic vessels with a diameter greater than 0.2 mm. have thicker walls in which three layers corresponding to the interna, media, and adventitia of arteries and veins can be distinguished. The boundaries between these layers are often indistinct.
4. The thoracic duct possesses a muscular media thicker than a vein of the same size.
5. Valves occur in pairs placed on the opposite sides within the lymph vessel. They prevent the lymph from reversing its direction.

K. HEART.

The heart is composed of three layers: the endocardium, the myocardium, and the epicardium. The first is continuous with the interna of the blood vessels; the myocardium corresponds to the media, and the epicardium to the externa except that its outer surface is covered with mesothelium.

1. ATRIA (AURICLES).
   a. Endocardium is thicker in the atria, especially in the left atrium, than in the ventricles.
   b. *Myocardium much thinner than in the ventricle.*
2. RIGHT VENTRICLE.
   a. *Compact part about one-third of entire thickness. Looser part (columna carneae) about two-thirds.*
3. LEFT VENTRICLE.
   a. *Compact part two-thirds, loose part one-third of entire thickness.*

4. PAPILLARY MUSCLE.
   a. Small area of heart muscle surrounded by endothelial cells (endocardium).
5. CHORDAE TENDINEAE.
   a. *Composed of collagenous and elastic fibers surrounded by endocardium (endothelial cells).*
   b. Any of the heart sections may show epicardium or endocardium.
6. VALVES.
   a. The valves of the heart are folds of endocardium.
   b. Atrioventricular valves consist of fibrous and elastic tissue. Although smooth muscle fibers are found on the atrial side of the valves, they are not likely to be observed except in specially prepared slides.
   c. Aortic and pulmonary valves are similar to those above, but contain no muscle fibers.
7. IMPULSE CONDUCTING SYSTEM.
   a. Atrioventricular bundle of His consists of strands of fibers that are larger than cardiac muscle fibers. First described by Purkinje, hence often called Purkinje fibers.
   b. Sinoatrial and atrioventricular nodes consist of a network of fibers whose meshes are filled with connective tissue.

Summary of the Histology of the Vascular System

	Blood Vessels	*Endothelium*	*Connective Tissue*	*Muscle*	*Tunica Interna (Intima)*	*Tunica Media*	*Tunica Adventitia (Externa)*
	CAPILLARIES About 8 microns	Present	Thin layer usually separates them from other tissue	None	None	None	None
ARTERIES	SMALL ARTERIES (Arterioles) 0.3 mm or smaller	Present	Elastic and collagenous fibers	Smooth	Endothelium and internal elastic membrane	Smooth muscle fibers	Loose connective tissue with longitudinally oriented elastic and collagenous fibers
ARTERIES	MEDIUM SIZED ARTERIES (Muscular type)	Present	Elastic and collagenous fibers	Smooth	Between endothelium and internal elastic membrane a few fibroblasts, elastic and collagenous fibers in larger vessels of this caliber	Thick muscle layer. As caliber increases thin elastic fibers appear between cells	Sometimes thicker than tunica media. External elastic membrane adjacent to media well defined. Loose connective tissue with elastic and collagenous fibers
ARTERIES	LARGE SIZED ARTERIES (Elastic type)	Present	Elastic and collagenous fibers	Smooth muscle fibers present but not abundant	Rather thick. Fibroblasts, collagenous and elastic fibers present. A few smooth muscle cells may be present	Mainly of elastic tissue	Relatively thin. Consists of elastic and collagenous tissue
VEINS	SMALL VEINS (Venules) About 20 microns	Present	Longitudinally directed collagenous fibers and fibroblasts surround endothelium	None	None	None	None
VEINS	About 45 microns	Present	Elastic and collagenous fibers	Smooth muscle cells between endothelium and connective tissue	None	None	None
VEINS	Over 200 microns	Present	Elastic and collagenous fibers	Smooth	Endothelium	Several layers of smooth muscle cells	Scattered fibroblasts and thin elastic and collagenous fibers

Summary of the Histology of the Vascular System.—(*Continued*)

	Blood Vessels	*Endothelium*	*Connective Tissue*	*Muscle*	*Tunica Interna (Intima)*	*Tunica Media*	*Tunica Adventitia (Externa)*
VEINS	Medium-sized Veins 2–9 mm.	Present	Elastic and collagenous fibers	Circular smooth muscle	Endothelium Sometimes inconspicuous connective tissue layer present	Mainly of circular smooth muscles between which are abundant longitudinal, collagenous fibers	Loose connective tissue with collagenous bundles and elastic networks
	Large-sized Veins	Present	Elastic and collagenous fibers	Smooth	Endothelium Sometimes inconspicuous connective-tissue layer present	Sometimes absent. When present mainly of circular smooth muscles between which are abundant, longitudinal collagenous fibers	Loose connective tissue containing elastic and mainly longitudinal collagenous fibers Adjacent to media, or, if absent, to interna, longitudinal layers of smooth muscles, and elastic networks
	Specialized Structures	May be incomplete	Little or none	None	None	None	None
LYMPHATICS	Lymphatic Capillaries	Present	None	None	None	None	None
	Lymphatic Vessels Less than 0.2 mm.	Present	Mainly longitudinal, collagenous, and elastic fibers	A few smooth muscle cells	None	None	None
	Lymphatic Vessels More than 0.2 mm.	Present	Elastic and collagenous fibers	Smooth	Endothelium and thin layer of longitudinal elastic fibers	Several layers of mainly circular smooth muscles and elastic fibers	Interlacing collagenous and elastic fibers, and smooth muscle fibers

9

Lymphoid Organs

Reticular tissue and lymphocytes together constitute the lymphoid or adenoid tissue proper of the so-called lymphoid organs. The lymph nodes have been termed the structural units of lymphoid tissue.

A. *LYMPH NODES (GLANDS).*

1. Generally round or oval.
2. Capsule of collagenous and elastic connective tissue.
3. Cortex.
   a. Peripheral (cortical, subcapsular) sinus appears as a pale staining area which lies immediately beneath the capsule.
   b. *Cortex contains nodules with germinal centers. Small arteries in nodules not sheathed as in spleen.*
4. Medulla.
   a. Medullary cords consist of dense lymphatic tissue which stains darkly.
   b. Cords are surrounded by sinuses which appear as light-colored areas.
5. Whole organ is more basophilic than the spleen.
6. *Pulmonary and bronchial lymph glands commonly contain considerable carbon particles.*

B. HEMOLYMPH GLANDS (HEMAL NODES).

1. Typical hemolymph gland resembles a lymph gland in its general structure.
2. Covered by a connective-tissue capsule from which a very few trabeculae enter the gland.
3. When nodules with germinal centers are present they are usually found in the cortex.
4. Entirely devoid of lymphatic vessels.
5. *Sinuses filled with erythrocytes.*

C. SPLEEN.

1. The spleen is much like a large lymph node, but the fibromuscular capsule is thicker and the trabeculae are larger.
2. *Fibromuscular trabeculae, which extend from the periphery into the substance of the gland, tend to be at right angles to the capsule.* This is a most distinctive

characteristic as the fibromuscular trabeculae persist after all other features disappear under pathological conditions.

3. Splenic pulp is divided into two varieties as follows:
   a. Red pulp contains all types of cells found in the circulating blood, and venous sinuses. *Erythrocytes give the characteristic red color to this part of the gland.*
   b. White pulp surrounds arteries and includes splenic nodules. This differs from the red pulp in containing large numbers of lymphocytes. *The areas of white pulp stain a deep purple in preparations dyed with hematoxylin and eosin.*
4. *Splenic nodules (Malpighian bodies, splenic corpuscles) with so-called central sheathed arteries are very diagnostic in the higher vertebrates.*
5. *Germinal centers of splenic nodules usually poorly defined.*
6. *No division into cortex and medulla.*

D. THYMUS.

1. YOUNG.
   a. Subdivided into lobes by connective tissue. These lobes subsequently divide into lobules.
   b. *Each lobule has a definitely darker cortex and a lighter medulla. Each lobule resembles a lymph gland, but germinal centers are not present and no lymph sinuses are found.*
   c. *Medulla, only, contains thymic (Hassall's) corpuscles,* which are eosinophilic and show an arrangement of concentric layers. Occasionally they are lacking.
   d. *No nodules in cortex,* but cortex consists of densely packed small lymphocytes which are termed *thymocytes* by some authors.
   e. *Medulla does not have cords of cells* and trabeculae as do the lymph glands.
2. ATROPHIC.
   a. *Adipose tissue with strands of lymphoid tissue.*
   b. These strands contain thymic corpuscles. The corpuscles are generally larger in old thymus. The clearly lobulated structure is lost, as is the cortex and medulla arrangement.

E. TONSIL. In tonsil tissue the epithelium is usually so infiltrated with lymphocytes that it stains darker and is less distinct than usual. A tonsil possesses no sinuses either for blood or for lymph.

1. LINGUAL TONSILS.
   a. Covered on free surface by a stratified squamous epithelium.
   b. *Relatively shallow, slightly branching crypts, lined with stratified squamous epithelium.*
   c. Crypts surrounded by lymph nodules with germinal centers. Clear central germinating area surrounded by a darker area of smaller more compact cells. Few crypts as compared with palatine tonsil.
   d. *No definite fibrous tissue capsule.*
   e. Tongue muscles and mucous glands which lie beneath the lingual tonsil may be associated with it in sections.
2. PALATINE (FAUCIAL) TONSILS.
   a. Covered on free surface by a stratified squamous epithelium. Epithelium may be infiltrated with lymphoid cells.
   b. *Contain many deep-branched crypts* (10–20), *and, when sectioned, oval or slitlike isolated spaces, lined with stratified squamous epithelium often appear.*
   c. Crypts surrounded by many lymph nodules.
   d. Exudate commonly found in crypts.
   e. Crypts are partly separated from one another by partitions of loose connective tissue.
   f. *A definite fibrous connective-tissue capsule invests the portion of the gland which is not bordered by epithelium.*
   g. Striated muscle which is frequently found external to the connective tissue of the capsule of a vertical section is evidence of the close relation of the tonsil to the underlying muscular structures.
   h. Cartilage plates may be present in old hypertrophied tonsils.
3. PHARYNGEAL TONSIL.
   Like palatine (faucial) tonsils except:
   1. *Less definite capsule.*
   2. Free surface covered for most part by pseudostratified ciliated epithelium; however, there may be patches of stratified squamous epithelium.
   3. Crypts generally absent but numerous folds lined with pseudostratified ciliated epithelium.
   4. If crypts present, may be lined with pseudostratified epithelium.
4. TUBAL TONSILS
   a. Small accumulations of lymphoid tissue about the openings of the Eustachian tubes into the pharynx.

Summary of the Histology of the Lymphoid Organs

	Organ	Capsule	Hilus	Cortex	Medulla	Epithelium	Nodules	Lymphatic Vessels	Lymphatic Sinuses
	LYMPH GLANDS	Connective tissue	Present	Nodules and diffuse tissue	Medullary cords of dense and diffuse lymphatic tissue	None	Present in cortex	Afferent and efferent	Peripheral and medullary
	HEMOLYMPH GLANDS	Connective tissue	Present	Irregular masses Nodes may be present	Anastomosing cords of tissue	None	Present	None	None. Sinuses contain blood
	SPLEEN	Elastic and collagenous fibers A few muscle cells present	Present	None	None	None	Around central artery	Only in capsule and trabeculae	None
	THYMUS	Connective tissue	None	Densely packed cells	Hassall's corpuscles	None	None	Penetrate lymphoid tissue	None
TONSILS	LINGUAL TONSIL	No definite fibrous-tissue capsule	None	None	None	Stratified squamous	With germinal centers Clustered around crypts	None	None
TONSILS	FAUCIAL TONSIL (Palatine)	Definite fibrous tissue capsule	None	None	None	Stratified squamous	Surround crypts Usually in a single layer under the epithelium	None	None
TONSILS	PHARYNGEAL TONSIL	Less definite than in faucial tonsil	None	None	None	Pseudostratified, ciliated	Surround crypts	None	None

10
Skin and Its Derivatives

A. SKIN.

It consists of an epidermis of ectodermal origin and a corium or dermis of mesodermal origin. It rests on a layer of connective tissue.

1. *EPIDERMIS. This is* a stratified squamous epithelium. *Its* thickness varies with the region of the body; it is thickest on the palms of the hands and the soles of the feet. Two layers, lucidum and granulosum, are usually absent in thin skin.
   a. In thick skin the following layers, from within outward, can be distinguished.
      (1) Stratum Germinativum (Malpighian Layer). It is dark staining and the nuclei are prominent. This layer can be divided into two sublayers as follows.
         (a) Basal Layer (Stratum Cylindricum). Consists of a single row of columnar cells with indistinct outlines. It gives rise to the layers above. Mitotic figures are frequently observed.
         (b) Spiny Layer (Stratum Spinosum). The cells are polygonal. They are somewhat flattened in the superficial layers. They are connected with each other by protoplasmic intercellular bridges which appear as spines on individual cells. For this reason the cells are called "prickle cells." These are seen only under high magnification of exceptionally good preparations.
      (2) Granular Layer (Stratum Granulosum). It consists of somewhat flattened cells, the cytoplasm of which contains a number of coarse deeply staining granules of keratohyalin. Intercellular bridges are present but difficult to observe. In ordinary preparations of vertical sections, the cells appear to be separated by narrow spaces so that each is surrounded by a light line.
      (3) Stratum Lucidum. A thin clear layer with indistinct nuclei and cell boundaries. *In sections the lucidum appears as a pale wavy stripe.*
      (4) Stratum Corneum. *A thick, poorly staining layer of progressively flattened and cornified (keratinized, horny) cells which possess no nuclei.*

2. CORIUM (DERMA). The corium roughly corresponds in thickness to the epidermis.
   a. The corium consists of two layers which are, from without inward:
      (1) Papillary Layer. It is a poorly demarked, superficial, dense, areolar connective tissue which contains blood vessels and nerves. Other structures supported by this layer of the corium are: (1) hairs and hair follicles, (2) sebaceous glands, and (3) sweat glands. It is called a papillary layer because it occupies elevations of the corium (papillae) which project into the lower surface of the epidermis.
      (2) Reticular Layer. A looser, coarser layer composed of areolar and adipose tissues. It merges with the subcutaneous tissue.
3. SUBCUTANEOUS TISSUE (TELA SUBCUTANEA, SUBCUTIS, HYPODERMIS).
   a. As the name implies, this layer is not a part of the skin proper but is inseparable from it. It serves to attach the skin to the deep fascia, muscles, and bones.
   b. It consists of widely separated bundles of fibroelastic tissues and masses (lobules) of fat cells which occupy the spaces between them.
4. PIGMENTATION. The color of the human skin depends chiefly on the presence of pigments. It is said that the human skin contains five different pigments, (1) melanin, (2) melanoid, (3) oxyhemoglobin, (4) reduced hemoglobin, and (5) carotene. No additional pigments are found in the darker races, the differences in color being due only to the amounts of pigment.

B. SKIN OF THE SCROTUM.

The skin of the scrotum has unique characteristics which merit special mention.

1. It possesses all the characteristics of thin skin; but, in addition, there are coarse scattered bundles of smooth muscle in the corium. While these scattered bundles of smooth muscle are very characteristic of the scrotum, they are also found in the nipple, prepuce, glans penis, and in the perianal region. The contraction of these muscle fibers gives the skin of these regions its wrinkled appearance.
2. Especially rich in pigment are certain other patches of skin such as the axillae, areolae, nipples, labia majora, and the circumanal region.

C. HAIR.

Hairs are elastic horny threads developed from the epidermis. They grow within deep narrow pits (hair follicles) in the corium which may extend to the subcutaneous tissue. Each hair consists of a shaft and a root which occupy the hair follicle.

The lower end of the root expands into a knoblike structure, the hair bulb.

1. HAIR STRUCTURE. Hair is made up entirely of epithelial cells which form three layers. They are, from within outward:
   a. MEDULLA. This forms the core of the hair. It consists of two or three layers of cuboidal cells. Their cytoplasm stains lightly. The medulla does not extend the whole length of the hair; therefore, it is not observed in all sections.
   b. CORTEX. It makes up the main bulk of the hair. It is composed of several layers of spindle-shaped cells with shrunken nuclei. In colored hair, pigment is found between the cells of this layer.
   c. CUTICLE. An exceedingly thin layer composed of a single layer of flat, non-nucleated cells which overlap each other like the shingles on a roof.
2. FOLLICLE STRUCTURE. The follicle consists of the inner and outer root sheaths derived from the epidermis, and an external connective-tissue sheath derived from the corium. See illustration on p. 101.
   a. INNER ROOT SHEATH (INNER EPITHELIAL SHEATH). It consists of three distinct layers which are from within outward: the cuticle of the root sheath, Huxley's layer (several rows deep), and Henle's layer (single row of somewhat flattened cells).
   b. OUTER ROOT SHEATH (OUTER EPITHELIAL SHEATH). It is a continuation of the stratum germinativum. It consists of several layers of cells; the outermost row is composed of rather tall cells (stratum cylindricum).
   c. CONNECTIVE-TISSUE SHEATH (THECA).
      (1) Inner Layer. Really a hyaline membrane between the epithelial tissue and the connective tissue proper.
      (2) Middle Layer. Consists of circular bundles of connective tissue.
      (3) Outer Layer. A poorly defined layer of loosely woven bundles of white fibers which run longitudinally.

d. HAIR BULB. Consists of a mass of epithelial cells. The multiplication of these cells causes the hair to grow in length.

e. HAIR PAPILLA. A vascular extension of connective tissue which penetrates into the enlarged hair bulb.

f. ARRECTORES PILORUM (HAIR MUSCLE). Minute smooth muscle fibers, which arise from the papillary layer of the skin, and are inserted in the connective-tissue sheath about the middle of the follicle.

D. GLANDS OF SKIN.

Sebaceous, sweat, and mammary glands are all derived from the skin. The latter is described in the section which deals with the female reproductive system.

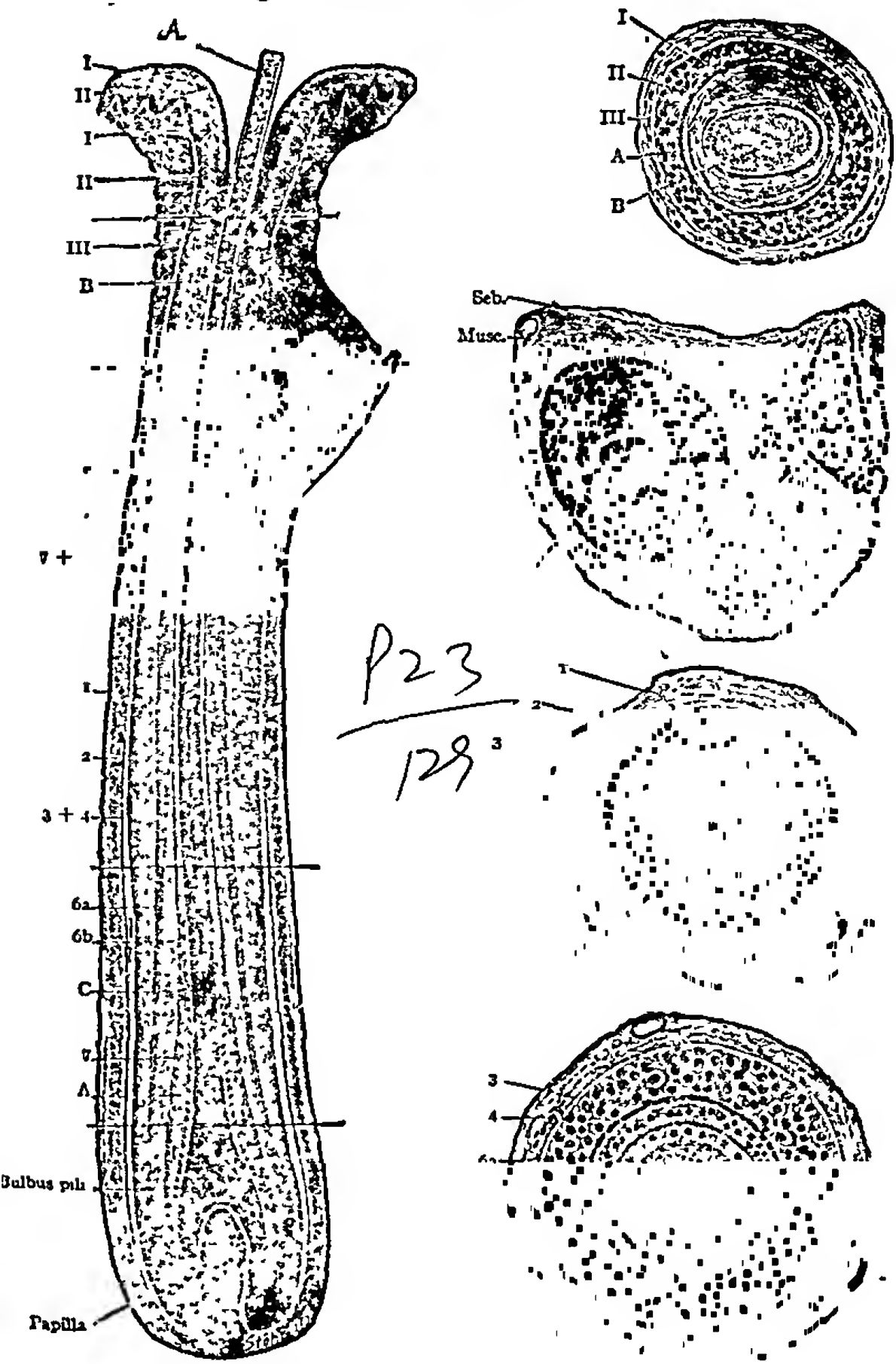
1. SEBACEOUS GLANDS. Usually associated with a hair follicle, but in exceptional cases, such as the margin of the lip or the labia minora, they open directly on the surface of the skin.
   a. TYPE OF GLAND AND SHAPE. Simple or branched alveolar glands. They are spherical or ovoid in shape.
   b. STRUCTURE. The sebaceous glands appear as large, light-staining, solid islands of polyhedral cells with many vacuoles in their cytoplasm. Ducts usually empty obliquely into hair follicles. Each gland is surrounded by a fibrous sheath.
2. SWEAT GLANDS (GLANDULAE SUDORIPARAE). They are found over the entire body surface, excepting the ear drum, the nail bed, the margin of the lips, the inner surface of the prepuce, and the glans penis. They are the only glands found on palms of the hands and soles of the feet.
   a. TYPE OF GLAND. Long simple coiled glands. Holmes described them as resembling a fairy's intestine. *In sections they can be recognized as nests of small cut tubules.*
   b. WALLS OF SECRETORY PORTION, FROM WITHOUT INWARD:
      (1) Basement membrane.
      (2) Myo-epithelial cells. Flattened spindle-shaped cells. They are contractile and develop from ectoderm.
      (3) Gland cells. They are cuboidal or low columnar, the height varying with activity.
   c. EXCRETORY DUCT. A thin tube which takes a pronounced spiral course in the epidermis.

E. NAILS.

The nails are modifications of the epidermis:

1. NAIL BED. This is the skin under the body of the nail. The epithelium of the nail corresponds to the stratum germinativum layer of the skin. The stratum granulosum, stratum lucidum, and stratum corneum are absent. The corium of the nail bed differs from that of ordinary skin in that the connective-tissue fibers are arranged partly longitudinally to the long axis of the nail, and partly in a vertical plane extending from the periosteum to the nail.
   a. MATRIX. This is the thickened germinativum which lies beneath the root and corresponds to the lunula. Growth of the nail results from a transformation of the superficial cells of the matrix into true nail cells.
2. NAIL BODY (NAILPLATE). This is the nail proper and consists of several layers of clear, flat, horny, scale-like cells.
3. EPONYCHIUM. This is the stratum corneum of the adjoining skin. It spreads over the upper surface of the nail root and forms the so-called "cuticle."
4. HYPONYCHIUM. This is the thickened stratum corneum of the skin just beneath the free edge of the nail.

Four Cross Sections of a Hair of a Head (× 160), with a Diagrammatic Longitudinal View



11.

Digestive System

A. LIPS (VERTICAL SECTION).

The layers from without inward are:

1. SKIN ON THE OUTSIDE. It consists of stratified squamous epithelium which is keratinized at the surface, and rests on a layer of connective tissue.
2. CONNECTIVE TISSUE. In this are sweat glands, sebaceous glands, and the bases of hair follicles.
3. STRIATED MUSCLE. Muscles of the lip consist of the orbicularis and the mimetic.
4. ORAL SURFACE.
   a. MUCOUS MEMBRANE. Like the lining of the soft parts of the oral cavity.
5. TRANSITION FROM SKIN TO MUCOUS MEMBRANE.
   a. The transition from skin to oral mucosa is marked by the following characteristics.
      (1) Epithelium becomes gradually thicker.
      (2) Gradual disappearance of keratinized cells.
      (3) The height of the connective-tissue papillae gradually decreases.
      (4) Disappearance of hair follicles and sebaceous and sweat glands.
      (5) Disappearance of pigmentation.
      (6) Appearance of labial (seromucous) glands in the connective tissue beneath the oral mucosa.

B. LINING OF THE MOUTH (ORAL) CAVITY.

1. MUCOSA (MUCOUS MEMBRANE).
   a. EPITHELIUM. It is stratified squamous. Its thickness varies in different parts of the oral cavity.
   b. TUNICA PROPRIA. It consists chiefly of fine areolar tissue which is thrown into papillae. It blends in most parts of the mouth with a submucosal layer.
2. SUBMUCOSA. This is composed of firm areolar tissue.
3. TISSUES BENEATH THE SUBMUCOSA. These vary in different parts of the mouth. In the cheeks, for example, the mucosa and submucosa lie against muscle. On the other hand, in the hard palate and the gingivae the layers in question lie directly against bone.

4. GLANDS. They are small branched structures present almost everywhere in the mouth except in the gums and hard palate. They contribute to the formation of saliva.
   a. MUCOUS GLANDS. These are light staining in ordinary hematoxylin-eosin preparations. The secretion is thick and slimy.
   b. SEROUS (ALBUMINOUS) GLANDS. Colored more strongly than mucous glands in hematoxylin-eosin stained preparations, therefore darker. They produce a watery fluid.
   c. MIXED (SEROMUCOUS) GLANDS. The relative number of mucous to serous cells varies considerably.

C. TONGUE.

1. MUCOSA (MUCOUS MEMBRANE).
   a. EPITHELIUM. Stratified squamous.
      (1) Lingual Papillae. The upper surface of the tongue is studded with projections known as lingual papillae.
         (a) Filiform Papillae. These are the most numerous and are distributed over the entire dorsal surface of the tongue. Each consists of a long slender central core of connective tissue covered by epithelium. The surface epithelium is keratinized.
         (b) Fungiform. They are so named because each somewhat resembles a mushroom. These are unevenly distributed among the filiform papillae.
         (c) Circumvallate (Vallate) Papillae. These are the largest papillae. The epithelium is not keratinized and contains taste buds. They are grouped along a V-shaped line on the posterior surface of the dorsum of the tongue. They are similar to the fungiform papillae in outline, but are surrounded by a deep furrow, or valley, from which they derive their name. The serous glands (of von Ebner) open at the bottom of the furrow. Other glands (mucous or mixed) also occur.
         (d) Foliate Papillae. These are well developed on the tongue of certain rodents such as the rabbit, but are rudimentary in man. In some animals they are parallel folds like the pages (folios) of a book, hence the name foliate. The foliate papillae are not intermingled with the filiform papillae, but occur in groups along the lateral margin of the posterior

part of the tongue. They have numerous well-developed taste buds.

2. TUNICA PROPRIA. It is composed of a layer of loose areolar tissue, which forms the core of the papillae.
3. *SUBMUCOSA.* Not present on the upper surface of the tongue, where the tunica propria unites directly with the connective tissue of the underlying muscle.
4. MUSCULATURE. The tongue can be easily identified by the characteristically complex musculature. *Although the bundles of striated fibers interlace in all directions, three fairly distinct planes—vertical, transverse, and longitudinal—can be differentiated.* The bundles of muscle fibers are embedded in areolar and adipose tissue.

D. TEETH.

1. GENERAL CONSIDERATIONS. A tooth consists of a crown, covered by enamel, and a root or roots implanted within the socket. The tooth is composed of enamel, dentine, and cementum, which are calcified tissues. In addition, each tooth has a vascular connective-tissue component, pulp, located within the pulp cavity. This cavity extends throughout the root as the root canal. Hardness of the tooth makes it impossible to prepare sections in the usual manner. Two types of sections of tooth are prepared: (1) Ground sections and (2) decalcified sections. However, only ground sections of mature enamel can be prepared.
2. ENAMEL. Enamel is the hardest tissue in the body. It is composed of slender rods or prisms separated by minute amounts of interprismatic substance.
3. DENTINE. It is somewhat harder than bone which it resembles in structure. However, it lacks cells and blood vessels.
   a. GROUND SUBSTANCE. Mature dentine is made up of a calcified component called apatite, and an organic component of fine collagenous fibrils arranged in bundles.
   b. DENTINAL CANALS. These begin at the dental pulp and extend outward radially to the periphery of the dentine. In the living state these tubules contain Tomes' dentinal fibrils. The tubules are arranged in the shape of a letter S in the crown.
4. CEMENTUM. Cementum forms a thin shell around the periphery of the root. Like bone tissue, it contains lacunae and bone cells (osteo-

cytes). Canaliculae radiate from the lacunae. Mainly, uncalcified Sharpey's fibers enter the cementum, which is normally nonvascular.

5. PERIDENTAL (PERIODONTAL) MEMBRANE. This is a layer of *dense fibrous* connective tissue, which anchors the tooth to the alveolus, attaches the teeth to each other, supports the free margin of the gingiva, and holds it to the tooth.
6. DENTAL PULP. It fills the pulp cavity.
   a. PULP TISSUE. It consists of a vascular connective tissue. The ground substance is *soft, gelatinous, and basophilic. It contains numerous* thin collagenous fibrils which are not combined into bundles but run in every direction. The pulp cells are similar to those of fibroblasts.
   b. ODONTOBLASTS. These are large, long, peripheral cells, whose processes pass into the dentinal canals. The odontoblasts produce dentine; therefore, they are comparable with osteoblasts.

E. PHARYNX.

1. Upper portion (nasopharynx) may be covered with stratified squamous, or pseudostratified ciliated columnar epithelium. Lower portion (oropharynx), lined with stratified squamous epithelium.
2. *Striated voluntary muscle not in definite layers.*
3. *No muscularis mucosae, but an elastic layer instead.*
4. Mucous or seromucous glands may penetrate the muscle layer.

F. ESOPHAGUS.

1. *Usually in a characteristically collapsed condition, and exhibits a flattened or stellate lumen.*
2. *Thick stratified squamous epithelium.* Papillated lower border.
3. Tunica propria narrow, solitary nodes (nodules).
4. Muscularis mucosae increases in thickness in the lower third of the esophagus. Consists of smooth muscle fibers longitudinally arranged.
5. Submucosa consists of thick collagenous and coarse elastic fibers.
6. Muscle *is in two definite* layers with nerve plexus (Auerbach's) between.
7. Muscle is all striated in upper third, mixed in middle third, and nearly all smooth in lower third.

8. Glands:
   a. *Esophageal glands, scattered, extending into submucosa* as tubulo-alveolar end-pieces; secretory portions in man composed only of mucous cells.
   b. *Cardiac glands,* terminal portions are branched. Mucous-like glands only. Found in the upper and lower parts of the esophagus. Similar to the glands in the cardiac portion of the stomach. *Confined to the tunica propria.* Individual variations and sometimes entirely absent.
   c. In some species no glands are found. *Examples:* rodents, cats, horses.
9. Outer coat of adventitia consists of loose fibroelastic tissue. The peritoneal lining covers that portion of the esophagus which extends below the diaphragm.

G. GASTRO-ESOPHAGEAL JUNCTION.

1. A longitudinal section through the esophagus at its junction with the stomach shows the following structural characteristics:
   a. Abrupt change from stratified squamous to simple columnar epithelium.
   b. The mucosa increases in thickness in making the transition. The muscularis mucosae is continuous across the junction, as are also the submucosa and muscle layers.
   c. The circular muscle layer increases in thickness to form the cardiac sphincter at the point where the esophagus joins the stomach.

H. STOMACH.

1. GENERAL STRUCTURE OF STOMACH WALL.
   a. MUCOSA.
      (1) Epithelium. Simple columnar.
      (2) Tunica propria.
      (3) Muscularis mucosae.
      (4) No villi but mucosa folded into ridges or rugae when stomach is not distended.
   b. SUBMUCOSA.
   c. MUSCULARIS.
      Usually described as consisting of three layers, but in the fundus, muscle fibers run in various directions. The demonstration of the muscle layers in sections is somewhat difficult.
      (1) Inner oblique layer of muscle.

(2) Middle circular layer of muscle.
(3) Outer longitudinal layer of muscle.

d. TUNICA SEROSA.
(1) Inner thin connective-tissue layer.
(2) Outer covering of mesothelium.

2. SPECIFIC REGIONS OF STOMACH.

a. CARDIAC.
(1) Simple columnar epithelium.
(2) *Goblet cells are absent in all parts of the stomach as contrasted with the intestine;* there may be very rare exceptions to this statement.
(3) No gastric glands extend into submucosa.
(4) *Cardiac glands of the stomach,* according to Bensely, occupy only a limited area adjacent to the esophagus.
(5) Bodies of the cardiac glands become shorter in passing from the cardiac region to the fundus of the stomach.
(6) *Scattered parietal cells may be found in the cardiac region.*

b. FUNDUS.
(1) *Gastric pits extend down into the mucosa less than one-half its thickness.*
(2) *Dark-staining gastric glands abundant in the mucosa, with many eosinophilic parietal cells.*
(3) *Glands shorter but more branched than in the cardiac stomach.*
(4) Gland tubule consists of neck, body, and fundus. The lumen is so narrow as to be almost imperceptible, and the effect produced is that of a cord of cells.
(a) Mucous neck cells.
(b) *Chief cells* (*central, peptic, or adelomorphous cells*): columnar, squarish or wedge-shaped predominate; *bluish-staining,* and granular.
(c) *Parietal cells* (*oxyntic or delomorphous cells*): large, clear, and *eosinophilic* (*pink*).
(5) Gastric (principal) glands occupy a much wider area than the fundus.

c. PYLORUS.
(1) *Gastric pits extend down into the mucosa more than one-half its thickness.*
(2) *Light-staining pyloric glands,* consisting of mucous-like cells above muscularis mucosae and *with very deep pits.* Cells similar in staining reaction to mucous.

(3) *The glands are of the simple branched type, but the divisions are more numerous, the lumen is larger, and the tubules more coiled than in the fundus.* Therefore, in perpendicular sections they are seldom seen as longitudinal structures.
(4) Few parietal cells.
(5) Solitary lymph nodules in cardiac and in pyloric portions of stomach.

3. GENERAL CONSIDERATIONS.
a. *Cardiac, fundic, and pyloric regions are not separated by sharply drawn limits.*
b. Along the border lines of these regions the glands of one mix with those of the other.

I. SMALL INTESTINE.

1. GENERAL STRUCTURE OF INTESTINAL WALL.
The layers from within outward are.
a. MUCOSA.
(1) Epithelium.
(2) Tunica propria.
(3) Muscularis mucosae.
(a) Inner circular muscle layer.
(b) Outer longitudinal muscle layer.
b. SUBMUCOSA.
c. MUSCULARIS.
(1) Thick inner circular layer.
(2) Thinner outer longitudinal layer.
d. TUNICA SEROSA.

2. SPECIFIC STRUCTURES OF INTESTINAL WALL.
a. VILLI.
(1) *Fingerlike projections of mucosa, surrounded by simple columnar epithelium with striated (cuticular) border.*
(2) When sectioned, portions of the villi may appear as islands of connective tissue surrounded by epithelium.
b. INTESTINAL GLANDS at base of villi.
c. INTESTINAL GLANDS (CRYPTS OF LIEBERKÜHN)
(1) When cross-sectioned, crypts appear as holes in the connective tissue lined with simple columnar epithelium.

d. PANETH CELLS.
   (1) Large pink-staining or clear sharp-edged eosinophilic granules are found in the cell cytoplasm at the bottom of the intestinal glands. Not found in dogs.

e. ARGENTAFFINE CELLS.
   (1) Their cytoplasm contains argyrophilic granules. These cells are scattered singly among other epithelial elements.

f. GOBLET CELLS.
   (1) More numerous as one approaches colon.

3. SPECIFIC REGIONS OF SMALL INTESTINE.

a. DUODENUM.
   (1) *Brünner's (duodenal) glands in the submucosa.* Presence of Brünner's glands in the upper duodenum is an identifying feature, but in the lower part of the duodenum these glands are absent. Gland cells stain like mucous cells.
   (2) *Villi are low, broad, leaf-like,* with intestinal glands (crypts of Lieberkühn) at their bases which extend to the muscularis mucosae but do not penetrate it.
   (3) If the bile duct shows in the wall, it is duodenum.

b. JEJUNUM.
   (1) *Villi taller and more slender with a more extensive development of the plicae circulares than in the duodenum.*
   (2) More goblet cells than in the duodenum.
   (3) *Solitary nodules do not extend into the submucosa.*

c. ILEUM.
   (1) *Few, short, club-shaped villi and scattered plicae.*
   (2) *Greater accumulations of lymphoid tissue than in jejunum.*
   (3) *Peyer's patches are to be found in that portion of the wall opposite the attachment of the mesentery.* They consist of flask-shaped nodules. The epithelium covering the area above the nodes is greatly reduced, and the villi are short or entirely absent.
   (4) More goblet cells than in the jejunum.
   (5) Nerves.
      (a) Myenteric (Auerbach's) plexus, located between circular and longitudinal muscles.
      (b) Submucous (Meissner's) plexus, located in the submucosa.

J. LARGE INTESTINE.

1. SPECIFIC REGIONS.

a. COLON.

(1) *Mucosa relatively smooth as compared with that of the stomach or small intestine. No villi. Tubular pits or glands present.* Lined with simple columnar epithelium.

(2) *More goblet cells than in small intestine.*

(3) Simple tubular glands, longer than those of small intestine; but, if cross-sectioned, are of about the same size at top and bottom.

(4) Paneth cells usually absent.

(5) *Solitary nodules of lymphoid tissue numerous.*

(6) *Outer longitudinal muscle layer is massed in three thick bands, the taenia (lineae) coli. In a given section the longitudinal muscle layer may be thick or thin depending on the presence or absence of the taenia coli.*

(7) Serosa contains lobules of fat which form pendulous projections, called appendices epiploicae.

b. VERMIFORM APPENDIX.

(1) Lumen which varies in size and shape is thrown into deep and pocketed folds.

(2) Lumen, frequently, totally or partially occluded as result of fibrosis in adult.

(3) *Fecal concretions frequently found in lumen.*

(4) Wall of appendix relatively thick.

(5) *No pits or villi.*

(6) *Large amount of lymphoid tissue which may extend into the submucosa.*

(7) Intestinal glands (crypts of Lieberkühn) more frequently branched than in colon.

(8) Usually no distinct muscularis mucosae because it is crowded out by lymphoid tissue.

(9) Inner circular and outer longitudinal muscle layers, but longitudinal layer differs from that of the large intestine in not being arranged into taeniae.

(10) The appendix is composed of the same tissue elements as those which form the mucosa of the colon, but in the appendix the glands are less numerous and there is much more lymphoid tissue.

c. RECTUM.

(1) *The intestinal glands are longer and contain a wider lumen than those of the colon.*

(2) *Goblet cells are present in such numbers that they form by far the greater portion of the epithelial lining of the crypts.*

(3) The longitudinal muscle of the taenia coli spreads out in the rectum to form a continuous coat of uniform thickness; however, it may be thickened on one or two sides.

d. ANAL CANAL.

(1) *Longitudinal sections in the lower portion show a transition from simple columnar to stratified columnar, and finally to stratified squamous epithelium* which is continuous with the skin in much the same fashion as the lip.

(2) Lower cutaneous portion may be confused with the lip.

(3) The skin may be identified by the hairs associated with it.

(4) Near anal opening, *circumanal glands* (similar to sweat glands).

(5) Circular layer of the muscularis coat is thickened around the anus to form two sphincters; the upper one of these is composed of smooth muscle, but the lower one consists of striated muscle.

Summary of the Histology of the Digestive System.

	Organ	Epithelium	Muscularis Mucosæ	Muscle Layers	Lymphoid Tissue	Glands		
						Name and Type	Position	Kinds of Cells
	PHARYNX	Upper portion, stratified squamous, stratified columnar, or pseudostratified ciliated. Lower portion, stratified squamous	Elastic layers instead of muscle	Striated voluntary muscle, not in two definite layers	Pharyngeal and palatine tonsils. Nodules and diffuse areas	Pharyngeal, simple branched, tubuloalveolar	Extend down into connective tissue and down into the edge of muscle	Mucous and seromucous
	ESOPHAGUS	Stratified squamous	Consists of longitudinal smooth muscle fibers and thin elastic network	Two layers. Upper third, inner circular and outer longitudinal striated muscle Middle third, circular and longitudinal striated and smooth muscle Lower third, circular and longitudinal smooth muscle. Exceptions in man where striated fibers are found even at cardiac orifice	Relatively few nodules in human, diffuse	Esophageal: mucous glands Branching tubuloalveolar glands Seromucous glands in some lower mammals	Extend into mucosa and submucosa	Mucous cells only in man. In some lower mammals mucous and serous occur
STOMACH	CARDIAC	Simple columnar	Inner circular and outer longitudinal, and in some places a third outer circular layer of smooth muscle	Inner oblique, middle circular, and outer longitudinal layers of smooth muscle. Oblique layer not distinguishable in some places	Small areas of lymphoid tissue in tunica propria adjacent to muscularis mucosæ. Some may extend into submucosa	Cardiac	Tunica propria and some may extend into submucosa	Mucous and occasional parietal cells
	FUNDUS	Simple columnar	Same as cardiac stomach	Myenteric (Auerbach's) plexus between circular and longitudinal muscle layers	Same as cardiac stomach	Gastric glands are simple branched tubular glands with short pits and long secreting pockets	Same as cardiac stomach	Chief cells, Parietal cells, Mucous cells
	PYLORUS	Simple columnar	Same as cardiac stomach	Myenteric (Auerbach's) plexus between circular and longitudinal muscle layers	Small nodules in tunica propria	Pyloric glands, chiefly simple branched tubular glands with deep pits and short secreting pockets	Same as cardiac stomach	Pale and mucous-like. Occasional parietal cells

Summary of the Histology of the Digestive System.—(*Continued*)

	Organ	Epithelium	Muscularis Mucosae	Muscle Layers	Lymphoid Tissue	Glands: Name and Type	Glands: Position	Glands: Kinds of Cells
SMALL INTESTINE	DUODENUM	Simple columnar	Inner circular and outer longitudinal layers of smooth muscle	Inner circular Outer longitudinal layers of smooth muscle Myenteric (Auerbach's) plexus between circular and longitudinal muscle	Solitary nodules and diffuse areas	1 Duodenal (Brünner's) glands compound tubular glands of mucous type 2 Intestinal (Lieberkühn) glands	Brünner's glands, chiefly in submucosa. Intestinal (Lieberkühn) glands above muscularis mucosae	1. Paneth cells, large cells in epithelium which lines distal portions of crypts Characterized by eosinophilic granules 2 Mucous cells of Brünner's glands 3 Cells of intestinal glands (Lieberkühn) 4 Goblet cells 5. Argentaffine cells between cells of intestinal glands
SMALL INTESTINE	JEJUNUM	Simple columnar	Same as duodenum	Same as duodenum	Same as duodenum	Intestinal glands simple tubular glands above muscularis muscosae	In small intestine and in large intestine above muscularis mucosae	Same as duodenum Small and large intestines possess goblet cells which increase relatively from upper to lower part of intestine
SMALL INTESTINE	ILEUM	Simple columnar	Same as duodenum	Same as duodenum	Aggregate (Peyer's) nodules and diffuse areas	Same as jejunum	Same as jejunum	Same as duodenum
LARGE INTESTINE	COLON	Simple columnar	Same as duodenum	Three longitudinal strands of smooth muscle (taeniae coli)	Solitary nodules and diffuse areas	Same as jejunum	Same as jejunum	Same as duodenum, except absence of cells of Paneth
LARGE INTESTINE	RECTUM	Simple columnar	Same as duodenum	Inner circular and outer longitudinal layers of smooth muscle	Solitary nodules	Crypts longer with wider lumen than those of jejunum	Same as jejunum	Increased number of goblet cells
LARGE INTESTINE	ANAL CANAL	Upper part, simple columnar which changes to stratified columnar, and finally stratified squamous in lower portion	Spreads out fanlike in rectal columns (columns of Morgagni) and forms the dilator muscle of Rudinger	Varies as to the region. Upper part smooth, near anus striated	Solitary nodules in submucosa	Lower portion sebaceous Near anal opening, circumanal (similar to sweat glands)	Varies with type of gland	Mucous and other types peculiar to different glands

12

Glands of the Digestive System

A. SALIVARY GLANDS.

1. PAROTID.
   a. *For the most part a purely serous gland.* Rarely mucous cells.
   b. Alveolar in structure. Also classified as acinar.
   c. *No islands or centro-acinar cells (see pancreas).*
   d. Intralobular (salivary) ducts lined with columnar epithelium.
   e. *Intercalated ducts lined with low cuboidal or flat epithelium.*
   f. The general structure is like that of the pancreas, but there are several marked differences: the parotid has many more ducts than the pancreas and it possesses no islands of Langerhans or centro-acinar cells. Parotid also stains darker with hematoxylin than pancreas.
2. SUBMAXILLARY (MANDIBULAR).
   a. Mixed serous and mucous cells (see p. 16 for description), with serous predominating; *about four-fifths serous, one-fifth mucous* in man. In cat and dog the submaxillary resembles the sublingual.
   b. *Most of the mucous alveoli have serous demilunes.*
   c. *Intercalated ducts.*
   d. *Secretory salivary ducts usually longer than in sublingual.*
3. SUBLINGUAL.
   a. *Mixed serous and mucous cells, with at least one-half mucous.*
   b. Chiefly mucous alveoli, but some serous demilunes.
   c. *Practically no intercalated ducts.*
   d. *Lymphoid tissue may be scattered through gland, especially in the connective-tissue septa.*
4. BUCCAL AND LABIAL.
   a. Seromucous, serous, and mucous glands.
5. PALATINE.
   a. Mucous type of cells.
6. LINGUAL GLANDS OF THE TONSIL REGION.
   a. Posterior one-third are mucous.
   b. Generally show some tongue muscle under and between the areas of gland tissue.
7. LINGUAL GLANDS NEAR CIRCUMVALLATE PAPILLAE.
   a. Serous.

b. A section often shows stratified squamous epithelium and tongue muscle.

B. PANCREAS.

1. Superficially resembles the salivary glands, especially the parotid, in structure.
2. *Spheroidal aggregations of light-staining cells, islands of Langerhans, usually found scattered through the tissue.* They are the most distinctive feature in the pancreas since they persist when the secretory acini have entirely disappeared as the result of a pancreatic pathology. May be absent in head of pancreas.
3. *Centro-acinar cells are present in the pancreatic acini.*
4. Acini of purely serous cells. Zymogen granules may often be observed in the cytoplasm.
5. Two-zone staining of pancreatic acinar cells with H. and E. is distinctive if and when it appears; this is due to basophilic basal striations and acidophilic apical cytoplasm.
6. *Interlobular connective tissue greater in amount and looser than in parotid.*
7. *Few ducts, 2 to 5 medium power (100 diameters) field.*
8. No intralobular secretory ducts lined with columnar cells.

C. LIVER.

1. *Lobules indefinite,* in man about two-thirds the size of medium power (100 diameters) field. Lobules definite in pig.
2. *Central vein and cord of hepatic cells radiating from it.*
3. May be blood in spaces (sinusoids) between the cords.
4. *Portal canals (islands of Glisson; trinities), located at periphery of lobule;* consisting of a little connective tissue, containing the *portal vein hepatic artery,* and one or more *bile ducts.*
5. Hepatic cells are large polyhedral cells with one or two eccentric, deeply staining, spherical nuclei.
6. Bile canaliculi, light dots between adjacent hepatic cells, are diagnostic if recognizable.

D. GALLBLADDER.

1. Epithelium is simple columnar; *oval nuclei near base; peripheral part large and clear. No goblet cells.*

2. *Mucous membrane is raised in a series of folds.* The tall primary folds give rise to secondary folds which unite with one another and enclose pockets of varying size. The pseudoglandular structures which result may extend well out into the muscular wall.
3. *Muscular wall is very unusual in that smooth muscle is interspersed with connective tissue. The muscles are arranged in small pencil-like bundles which are separated by connective tissue.*
4. *Entire wall is thin compared with the intestine.*

E. COMMON BILE DUCT.

1. *Epithelium consists mainly of tall columnar cells, resembling cells of the gall-bladder, but is unlike the gallbladder epithelium in that goblet cells are found here and there in the epithelium.*
2. Branched, tubular, mucus-secreting glands in the subepithelial layer.

13
Respiratory System

The respiratory system consists of the lungs and tubes by which air passes to them from the nasal cavity and nasopharynx. In the tubes there is a gradual change in structure from thick-walled rigid structures to thinner and softer tubules, a change somewhat like that occurring in the blood vessels.

A. NASAL CAVITY.

1. VESTIBULE.
   a. Lined with stratified squamous epithelium continuous with the skin of the nose.
2. OLFACTORY REGION (described in detail on p. 198).
3. RESPIRATORY REGION.
   a. Pseudostratified ciliated columnar epithelium.
   b. The subepithelial connective tissue is not differentiated into a distinct tunica propria and submucosa. Many seromucous glands present.

B. PHARYNX.

1. The epithelium of the nasal portion is stratified squamous or pseudostratified ciliated columnar; the oral portion is lined by stratified squamous. Mucous and seromucous glands are present. Lymphoid tissue abundant in the upper part.

C. LARYNX.

1. *Epithelium chiefly pseudostratified ciliated columnar; but where the surface is exposed to friction or abrasion, as over the true cords and epiglottis, stratified squamous is found.* At junction of these two types stratified ciliated columnar may be present.
2. There is a definite basement membrane but *no muscularis mucosae.* There is no sharp demarcation between the mucosa and submucosa.
3. Cartilages of the larynx are: epiglottis, thyroid, cricoid, cuneiform, corniculate, and arytenoids, the latter three appear in pairs. The cartilages are usually hyaline with the exception of the epiglottis, cuneiform, corniculate, and parts of the arytenoids in which yellow elastic tissue occurs.
4. There are two sets of muscles, extrinsic and intrinsic. The extrinsic muscles connect various parts of the larynx with surrounding muscles

and tissues. The intrinsic muscles run between different cartilages of the larynx.

5. True vocal cords have striated muscle; false vocal cords are muscleless.
6. *Mucous and seromucous glands.*
7. May be lymph glands craniad of the ventricle.
8. Because the pharynx constitutes a transitional region, different structural conditions obtain in different parts.

D. TRACHEA.

1. *Chiefly tall columnar, pseudostratified, ciliated epithelium.* Numerous goblet cells scattered through the epithelium.
2. Prominent basement membrane.
3. No muscularis mucosae in the mucosa but where it would be expected there is a rather prominent layer of elastic fibers.
4. Seromucous glands generally found in the submucosa.
5. *Supported by incomplete rings of hyaline cartilage, either oval in cross section, or long pieces in longitudinal section.*
6. The posterior part of the trachea has no cartilage but has considerable smooth muscle (trachealis) connecting the free ends of the semilunar (C-shaped) cartilages. Longitudinal fasciculi of muscle may be present although the muscle bundles run transversely for the most part.

E. BRONCHI.

1. Primary bronchi have the same structure as the trachea, but in their subdivisions changes occur as follows:
   a. Epithelium, although continuing as pseudostratified columnar type, decreases in height as the tubes become progressively smaller.
   b. *C-shaped cartilaginous ring is replaced by irregular plates of cartilage which more or less encircle the tubes.*
2. Mucosa appears wavy in cross section because of the longitudinal folding due to the contraction of muscle.
3. Seromucous glands are in mucosa, especially between the cartilages, and may spread out below them.
4. Smooth muscle in the mucosa; the amount of cartilage decreases as the amount of muscle increases.
5. *May have lung tissue or lymph nodules in a section.*

F. BRONCHIOLES.

1. The ciliated epithelium varies from columnar to cuboidal as the tubes become smaller. In the smallest *respiratory bronchioles the cubical* cells are not ciliated.
2. The mucosa of the terminal bronchioles is folded longitudinally. *The mucosa shows marked waviness in cross section.*
3. Cartilage disappears when the diameter of the bronchiole reaches 1 mm. in diameter. The glands also are absent but goblet cells still occur.

G. LUNG.

1. Alveolar ducts can be identified as communicating spaces whose walls are closely beset with thin-walled out-pocketings, the alveolar (air) sacs. The intervening portions consist of strands of collagenous and elastic fibers and smooth muscle cells.

   In tissues which have lost all nuclear staining power, lung alveoli can be recognized by the fact that the ultimate alveolar spaces are separated in part from one another by incomplete septa. *This is the only place in the body in which incomplete septa can be found in a structure of this general pattern.*
2. *May contain bronchi or bronchioles.*
3. Many conspicuous black particles of carbon may be present in the cytoplasm of dust cells (alveolar phagocytes). These cells are identical with the histocytes (macrophages) elsewhere in the body.
4. Visceral layer of the pleura envelops the lung. The surface of the pleura is covered with a mesothelium which rests upon a submesothelial layer of connective tissue.
5. Lymphoid tissue may or may not be prominent. Lymph glands are present at the origin of the larger bronchial branches.

Summary of the Histology of the Respiratory System

	Organ	Epithelium	Tunica Propria	Muscle Layers	Glands		
					Name and Type	Position	Kinds of Cells
NASAL CAVITY	VESTIBULE	Stratified squamous	Collagenous and elastic fibers with papillae	None	Sebaceous and sweat glands	Subepithelial connective tissue	Sebaceous and sweat gland cells
	OLFACTORY REGION	Pseudostratified	Collagenous and elastic fibers, in deep portion blends with periosteum	None	Olfactory (Bowman's) glands Branched tubular	Stroma	Serous
	RESPIRATORY REGION	Pseudostratified ciliated On conchae, varies from simple columnar on under surface to pseudostratified and even stratified squamous on upper surface	Collagenous and elastic fibers, toward bone merge with periosteum. *Very vascular*	None	Branched tubular	Subepithelial connective tissue	Goblet cells. Mucous and serous
TUBES	PHARYNX	Upper portion, stratified squamous, or pseudostratified ciliated columnar Lower portion stratified squamous	Collagenous and elastic fibers Contains many lymphocytes and nodules (pharyngeal tonsil)	Striated voluntary muscle, not in two definite layers	Pharyngeal, simple branched, tubuloalveolar. Mucous and *seromucous glands*	Extends down into connective tissue and edge of muscle	Mucous and serous
	LARYNX	For most part pseudostratified ciliated columnar, *Where friction* or abrasion, stratified squamous as over true vocal cords and epiglottis	Collagenous and elastic fibers Lymphocytes *and solitary nodules* present. Whole layer much reduced	Extrinsic muscles. Intrinsic muscles Muscles associated with true vocal cords	Branched tubular	Stroma, and may extend down into intermuscular connective tissue	Mucous and serous
	TRACHEA	Chiefly pseudostratified ciliated columnar	Collagenous and elastic fibers Lymphoid tissue diffuse and in the form of nodules Whole layer wider	Between free ends of cartilage, smooth muscle (trachealis)	Tracheal glands, simple branched, usually present	Submucosa	Goblet cells. Mucous and serous

Summary of the Histology of the Respiratory System.—(*Continued*)

	Organ	Epithelium	Tunica Propria	Muscle Layers	Glands		
					Name and Type	Position	Kinds of Cells
LUNG	Bronchi	Pseudostratified ciliated columnar	Collagenous and elastic fibers Lymphocytes present Entire layer reduced	Smooth circular muscle In primary bronchi same as trachea	Bronchial glands, branched tubular	Usually between cartilages	Same as trachea
	Bronchioles	Ciliated or nonciliated, columnar or cuboidal	Further reduced Collagenous and elastic fibers	Smooth circular muscle	None	None	None
	Respiratory Bronchioles	*Low columnar*, cuboidal, or squamous	Collagenous and elastic fibers	Smooth muscle fibers	None	None	None
	Alveolar Ducts	Squamous	Collagenous and elastic fibers	Strands of smooth muscle fibers	None	None	None
	Alveoli (Air Sacs)	Controversial point	Elastic and reticular fibers	None	None	None	None

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Urinary System

A. KIDNEY.

1. CORTEX.

a. Thin, eosinophilic, connective-tissue capsule on surface.

b. *Renal corpuscles distinctly blue when stained with H. and E. Generally appear as rounded cellular masses.*

c. *Labyrinth (pars convoluta) of cut tubules between renal corpuscles.*

(1) Proximal tubules 57–60 microns in diameter. Cells are low columnar or truncated pyramidal in form and *strongly eosinophilic. Free surface of cells possesses a brush border which is not found in any other part of the uriniferous tubule.* The brush border is seldom seen in routine preparations because it undergoes rapid postmortem changes. Cell boundaries are usually difficult to make out.

(2) Distal convoluted tubules 22–50 microns in diameter. *Distinguished from proximal convoluted tubules in that the cells are lower, more cuboidal, smaller, less eosinophilic, and show no brush border.*

d. Medullary rays may show with very low power.

2. MEDULLA.

a. *A solid mass of cross or longitudinally sectioned tubules of three sizes:*

(1) Henle's loop:

(a) Descending limb is about 8–20 microns in diameter. Thick part like proximal convoluted tubule. Thin segment composed of low cuboidal or much flattened cells. It may be mistaken for a capillary.

(b) Ascending limb is about 20–30 microns in diameter. Thick part is lined with cuboidal epithelium.

(2) Collecting tubules vary in diameter from 40–200 microns with large lumen; lower portion, columnar epithelium; upper portion, cuboidal epithelium. *The epithelium lining all parts of the collecting tubules has a faintly staining cytoplasm, round dark-staining nuclei, and distinct cell membranes.*

3. PELVIS.

a. Lined with transitional epithelium.

b. Thin mucosa.

c. Two layers of felted smooth muscle.

B. URETER.

1. MUCOSA.
   a. *Irregular lumen lined with transitional epithelium.*
   b. Tunica propria and submucosa merge together.
      (1) Delicate white fibers, with which a few elastic fibers are intermingled.
   c. No muscularis mucosae.
2. MUSCULARIS: consists of coarse bundles with connective tissue among them.
   a. PROXIMAL PART (UPPER HALF).
      (1) *Inner longitudinal layer.*
      (2) *Outer circular layer.*
   b. DISTAL PART (LOWER HALF).
      (1) Same as proximal except for a third outer longitudinal muscle layer.
3. ADVENTITIA (FIBROSA).
   a. Loose fibroelastic connective tissue.
   b. *Much adipose tissue, often associated with the outer part of adventitia.*

C. BLADDER.

1. MUCOSA.
   a. *Folded Surface.*
      (1) *Transitional epithelium, two-layered in distended bladder and as many as eight layers in the contracted condition.*
      (2) Pits in epithelial surface may be seen which may or may not possess a lumen.
   b. *Tunica Propria and Submucosa.*
      (1) These are blended together.
   c. *No Muscularis Mucosae.*
2. MUSCULARIS.
   a. *Rather thick muscular coat* made up of smooth muscle fibers. Usually not in distinguishable layers.
3. SEROSA.
   a. Connective tissue covered by mesothelium.
   b. In the nonperitoneal part, it is replaced by a fibrous layer.

D. URETHRA OF FEMALE.

1. Resembles structurally the penile urethra of the male throughout the greater part of its course.
2. Epithelium.
   a. Transitional epithelium of bladder continued into upper part of urethra; lower portion lined by stratified squamous epithelium. Epithelium of intermediate portion may be stratified columnar, pseudostratified, or even simple columnar.
3. *The lumen is irregularly crescentic or U-shaped and appears collapsed.*
4. *Branched tubular urethral glands may be present.*
5. *Subepithelial connective tissue is very vascular, constituting the corpus spongiosum.*
6. Skene's ducts (para-urethral glands) just within meatus, very characteristic but not often observed. They are subject to infection.

E. URETHRA OF MALE.

1. PROSTATIC PART (PARS PROSTATICA).
   a. Lumen irregular in shape.
   b. Lined by transitional epithelium.
   c. Muscularis of inner longitudinal and outer circular layers.
2. MEMBRANOUS PART (PARS MEMBRANACEA).
   a. *Stratified columnar or pseudostratified epithelium.*
   b. Muscular layers of inner longitudinal and outer circular layers.
   c. Bulbo-urethral (Cowper's) glands open near the cavernous portion. Their ducts are lined with low epithelium, which is surrounded by thin rings of smooth muscle.
3. CAVERNOUS PORTION (PARS CAVERNOSUM).
   a. *Stratified columnar or pseudostratified epithelium.*
   b. *Urethral glands (of Littré)* consisting of small groups of mucous cells which are continuous with the *lacunae of Morgagni.*
   c. Oblique and longitudinal bundles of smooth muscle fibers.
4. DISTAL END.
   a. *Epithelium of stratified squamous tissue at the end in the fossa navicularis.*
   b. *Papillae of tunica propria prominent.*

Summary of the Histology of the Urinary System

	Organ	Epithelium	Tunica Propria	Muscle Layers	Adventitia
KIDNEY	Bowman's Capsule	Flattened	None	None	None
	Proximal Convoluted Tubule	Pyramidal cells with brush border	None	None	None
	Descending Limb of Henle	Usually thin segment present, which consists of low cuboidal or flattened epithelium	None	None	None
	Loop and Ascending Limb of Henle	Usually thick segment present, which consists of simple cuboidal epithelium	None	None	None
	Distal Convoluted Tubule	Simple cuboidal without brush border	None	None	None
	Junctional (Arched) Tubule	In man same as distal convoluted tubule	None	None	None
	Collecting Tubule	Upper portion, cuboidal Lower portion, columnar Variable epithelium	None	None	None
	Papillary Ducts	Simple columnar	None	None	None
	Calyx	Transitional	Elastic and reticular tissue	Inner longitudinal and outer circular layers of *smooth muscle*	Connective tissue, fibroelastic
	Pelvis	Transitional	Elastic fibers and reticular tissue	Inner longitudinal and outer circular layers of smooth muscle	Fibroelastic tissue
	Ureter	*Transitional*	*Collagenous and* elastic fibers	*Upper portion: inner* longitudinal, outer circular. Lower portion inner longitudinal, middle circular, outer longitudinal	*Loose fibroelastic* tissue. Adipose tissue present
	Bladder	Transitional	Elastic and reticular tissue	Inner longitudinal Middle circular Outer longitudinal	In nonperitoneal part, fibrous
URETHRA	Urethra (*Female*)	Upper portion, transitional *Middle portion*, stratified columnar, or pseudostratified Lower portion, stratified squamous	Loose connective tissue with elastic fibers Vascular	Inner longitudinal and outer circular layers of smooth muscle External sphincter of striated muscle	Fibroelastic tissue
	Urethra (Male)	mous		Prostatic and membranous portions, inner longitudinal, outer circular. Cavernous portion bundles of smooth muscle	Fibroelastic tissue

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Male Reproductive System

A. TESTIS (TESTICLE).

1. Tunica (surrounds testis at periphery).
   a. ALBUGINEA—elastic fibers.
   b. VASCULOSA—very vascular.
   c. CONNECTIVE-TISSUE SEPTA *extend from albuginea into mediastinum,* dividing testis into pyramidal lobules.
2. *Convoluted* (*seminiferous*) *tubules* in lobules. In sections, one may get any view of tubules due to their convolutions. *Thus they may appear as ovals, question marks, C's, U's, or S's.* The form of the cut tubule is a valuable identification character.
   a. GERMINAL EPITHELIUM. From periphery to lumen: spermatogonia, primary spermatocytes, secondary spermatocytes, and spermatids. With the exception of the spermatids, these germinal cells are actively undergoing division and therefore the nuclei stain darkly.
   b. SUSTENTACULAR (SERTOLI) CELLS. Tall cells, irregular in outline, which extend from the basement membrane to the lumen. They support the germinal cells. *The oval nucleus is paler than the nucleus of any of the germinal cells.*
   c. INTERSTITIAL CELLS (CELLS OF LEYDIG).
      (1) Usually occur in dense compact groups of various sizes lying in the stroma of the angular spaces between the tubules.
      (2) Fairly large cells which are ovoid or polygonal in shape. Nucleus is large and often eccentrically located. The cytoplasm stains lightly.
   d. *Spermatozoa may be present in the lumen.*
3. Tubuli recti (straight tubules) are continuous with convoluted tubules. They are lined with simple epithelial cells which vary from flat to columnar.
4. The tubuli recti pass into the mediastinum where they empty into the *rete testis, a branching network of cavernous-like spaces in the mediastinum, lined with cuboidal or squamous epithelium* and surrounded by dense connective tissue.

B. DUCTULI (TUBULI) EFFERENTES (VASA EFFERENTIA).

These are tubules leading from the rete testis to the epididymis.

1. *Epithelium is peculiar in that it consists, mainly, of two kinds of cells, groups of high columnar ciliated cells alternating with cuboidal cells which are usually not ciliated.* This type of epithelium gives the lumen an irregular outline.
2. *Circular smooth muscle. Little muscle as compared with the ductus deferens.*

C. DUCTUS EPIDIDYMIS.

1. *Lumen of tubules lined with an epithelium which consists of a basal layer of small cells and a surface layer of tall columnar cells.* Tall cells and occasionally short ones are stereociliated. Variously classified as pseudostratified or stratified columnar.
2. *Tubules with thin fibromuscular walls.*
3. Masses of spermatozoa often found in the lumens of the tubules.
4. *Spaces between tubules filled with a loose connective tissue.*

D. DUCTUS DEFERENS (VAS DEFERENS).

1. *Mucous membrane typically folded in cross section.*
2. Small lumen lined with pseudostratified epithelium which may or may not be stereociliated. The epithelium is lower than in the epididymis; but near the epididymis, the epithelium is like that of the ductus epididymis. Some authors describe the epithelium as columnar nonciliated.
3. *Very thick, dense, muscular wall of interlacing fibers, which consists of the following layers: inner and outer longitudinal, and middle circular. Inner longitudinal layer poorly developed.* In proportion to the diameter of its lumen the ductus deferens is one of the most heavily musculated tubes in the human body.
4. Generally one to several arteries present outside of muscle, but no large vessels in muscle wall.
5. Adventitia (fibrosa) of connective tissue.

E. AMPULLA OF DUCTUS DEFERENS.

1. Epithelium is cuboidal or columnar.
2. Mucosa is thrown into numerous branching folds which in many places fuse with one another, thus in section appearing netlike.

3. *Resembles the seminal vesicles but has fewer lumina. Sperms are rare or absent in the secretion of the seminal vesicles but are common in the secretion of the ampulla.*

F. EJACULATORY DUCTS OF DUCTUS DEFERENS.

1. Epithelium is simple columnar or pseudostratified.
2. Mucous membrane forms many thin folds reaching far into the lumen; its connective tissue is provided with abundant elastic networks.
3. The ducts are surrounded by connective tissue.

G. SEMINAL VESICLES OF DUCTUS DEFERENS.

1. Epithelium shows variations which probably depend on age and functional influences. *It is usually pseudostratified but may be columnar, varying from one to two layers.*
2. *Mucous membrane, much folded, with the folds uniting to form a reticulated surface.*
3. *Vesicles may contain a granular secretion which stains strongly with eosin.*
4. Muscular walls consist chiefly of circular muscles, external to which there may be scattered longitudinal fibers.
5. Sections of the seminal vesicles can be distinguished from gallbladder by the fact that they have a thinner muscular coat than that of gallbladder.

H. PROSTATE GLAND.

1. *Epithelium, simple columnar or cuboidal.* May appear pseudostratified in places.
2. *Mucous membrane much corrugated in appearance.*
3. Alveoli may contain a finely granular secretion.
4. Lamellated, concentric, pink concretions (corpora amylacea) frequently found in the alveoli. Lamellations not always evident. More numerous after middle age.
5. *Fibromuscular stroma.* Muscles and connective tissue constitute about one-third or more of organ. *Note particularly the abundance of discrete single muscle fibers arranged in small interlacing bundles.* This is said to be the only region in the body where this feature is found.

I. BULBO-URETHRAL (COWPER'S) GLANDS.

1. The epithelium is subject to great functional variations. In the enlarged alveoli the cells are usually flat; in the other glandular spaces they vary from cuboidal to columnar.

2. The interstitial connective tissue contains both smooth and striated muscle with elastic nets.

J. PENIS.

1. The penis proper consists of three cylindrical bodies.
   a. *Two corpora cavernosa penis located dorsally.* The dorsal artery and vein are located in the subcutaneous connective tissue dorsal to the corpora cavernosa penis.
   b. One corpus cavernosum urethrae (corpus spongiosum) ventral in position. Surrounds the urethra.
   c. The tunica albuginea, a fibrous membrane, surrounds each of the cavernous bodies.
2. *Main substance of the organ is erectile tissue,* which consists of large, irregular, endothelium-lined, venous spaces known as cavernous spaces or lacunae. These are surrounded by connective tissue.
3. Glans penis.
   a. The rounded end of the penis is called the glans penis.
   b. It is covered with a stratified squamous epithelium continuous with the lining of the urethra and also peripherally with the skin of the prepuce.
   c. It consists of dense connective tissue containing nets of anastomosing veins, with circular and longitudinal smooth muscles in their walls.
   d. Richly supplied with sensory nerve endings.
   e. The glans is covered by a prepuce (foreskin) which is composed of thin skin with smooth muscle layer in subcutaneous layer. *Free from large hair follicles.* Small sweat and modified sebaceous glands (glands of Tyson) may be present. Inner surface adjacent to the glans has the character of a mucous membrane.

Summary of the Histology of the Male Reproductive System

	Organ	Epithelium	Muscle Layers	Connective Tissue
TESTIS	CONVOLUTED TUBULES	Special type composed of sustentacular (Sertoli) cells and germinal cells From periphery to lumen, the germinal cells are spermatogonia, primary spermatocytes, secondary spermatocytes, and spermatids	None	*Basement membrane* strengthened by lamellated connective tissue
	TUBULI RECTI (Straight Tubules)	Simple epithelium which varies from columnar to flat	None	Surrounded by dense connective tissue of mediastinum
	RETE TESTIS	Cuboidal or simple squamous	None	Surrounded by dense connective tissue of mediastinum
DUCTS	[illegible]	[illegible]	Thin circular layer of [illegible] scle	Loose connective tissue in spaces between tubules
	[illegible]	[illegible] ated	[illegible] of smooth	Loose connective tissue in spaces between tubules
	DUCTUS DEFERENS (Vas Deferens)	Pseudostratif[illegible] epididymis, same as ductus epididymis	[illegible] longitudinal layers of smooth muscle	[illegible] tains extensive elastic networks Adventitia of connective tissue
	AMPULLA OF DUCTUS DEFERENS	Cuboidal or columnar	Less regularly arranged than in other parts of ductus deferens	Tunica propria and adventitia
	EJACULATORY DUCTS OF DUCTUS DEFERENS	Simple columnar or pseudostratified	*Muscularis* present at beginning	Connective tissue provided with extensive *elastic networks*
ACCESSORY GLANDS	SEMINAL VESICLES	*Individual variations* Usually pseudostratified but may be columnar, varying from one to two layers	Smooth muscle fibers, chiefly circular, external to this layer, longitudinal fibers may be present	Tunica propria rich in elastic fibers Wall of external connective tissue with elastic nets
	PROSTATE GLAND	Simple columnar or cuboidal May appear pseudostratified in places	Smooth muscle fibers in interstitial tissue	Vascular connective tissue with dense elastic networks beneath epithelium *Interstitial* connective tissue dense with collagenous fibers and elastic networks
	BULBO-URETHRAL GLANDS (Cowper's Glands)	Subject to functional variations In enlarged alveoli, usually flattened In other glandular spaces the cells vary from cuboidal to columnar	Striated and smooth muscle in interstitial tissue	Connective tissue has elastic networks
PENIS	CORPORA CAVERNOSA	Endothelium	[illegible]	[illegible] and elastic tunica albu
	CORPUS CAVERNOSUM URETHRAE (Corpus Spongiosum)	Endothelium	[illegible]	[illegible] lastic networks iea Numerous ers in septa
	GLANS PENIS	Stratified squamous	Circular and longitudinal *smooth muscle* in walls of veins	Dense connective tissue containing network of anastomosing veins

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Female Reproductive System

A. OVARY.

1: CORTEX:

a: Germinal epithelium on the surface of the ovary of the embryo is simple cuboidal or columnar, but in the adult it is typically cuboidal.

b. *May show ova or follicles in the following stages of development:*

(1) *Primary follicle* or *oöcyte* (*ovocyte*) showing oöcyte enclosed by a single layer of flattened or cuboidal follicular cells and surrounded by interstitial tissue.

(2) Follicle showing the beginning of the zone of growth, that is, a large ovum (oöcyte) enclosed by a *zona pellucida* which is surrounded by high, cylindrical, radiating, follicular cells. The immediately surrounding stroma is compressed into a *theca folliculi.*

(3) More advanced stage showing further enlarged ovum with a more distinct *zona pellucida* surrounded by a solid mass of columnar, radiating, follicular cells, forming the *corona radiata.* Theca folliculi more developed.

(4) Mature (Graafian) follicle. The follicle becomes greatly enlarged and assumes an ovoid shape. The follicular cells increase, and a follicular cavity (*antrum folliculi*) with its contained fluid (liquor folliculi) develops. As this fluid increases, the ovum is pressed to one side, where it is surrounded by an accumulation of follicular cells (*cumulus oöphorus*). Elsewhere the follicular cavity has an epithelium of fairly uniform thickness called the *membrana granulosa.* The theca folliculi is divided into the *theca interna* and the *theca externa.*

(5) Summary of the principal structures of a mature Graafian follicle. The structures are listed in order from without, inward:

(a) Theca folliculi { tunica externa. / tunica interna. / glassy membrane.

(b) Membrana granulosa.

(c) Liquor folliculi—filling the antrum folliculi.

(d) Cumulus oöphorus (discus proligerus).

(e) Corona radiata.

(f) Zona pellucida (oölemma).
(g) Vitelline membrane.
(h) Egg cytoplasm (vitellus).
(i) Nucleus.
(j) Nucleolus (germinal spot).

c. May show corpus haemorrhagicum, corpus luteum, or corpus albicans
d. *Stroma of the ovarian cortex is a dense connective tissue, which may be arranged in a whorl-like pattern.* Very little if any smooth muscle except near the medulla.

2. MEDULLA.
   a. *Consists of a fibromuscular stroma.*
   b. *Many thin-walled blood vessels* in the medulla make it highly vascular, in sharp contrast with the cortex.

B. CORPUS LUTEUM OF OVARY.

The ruptured follicle does not degenerate immediately after ovulation, but is transformed into a yellow glandular structure known as the corpus luteum.

1. The corpus luteum is large enough to be seen without magnification.
2. The lutein cells are polyhedral in form but often without definite cell walls. They are large cells with clear cytoplasm. They are arranged in irregular masses.
3. In the human, large folds surround a central cavity which is filled with loose connective tissue.

C. OVIDUCT (UTERINE OR FALLOPIAN TUBE).

1. FIMBRIA AND AMPULLA. Includes distal two-thirds of the duct.
   a. *Epithelium is simple columnar, some cells of which are ciliated.*
   b. Subepithelial connective tissue very loose and contains many thin-walled blood vessels.
   c. *Near the fimbriated extremity the mucous membrane is thrown into complicated folds which are tall and branched and may show anastomoses.*
   d. *Folds less complex in ampulla than in fimbria, hence lumen is more evident in the ampulla.*
   e. Muscularis consists of inner circular and outer longitudinal layers of smooth muscle.
2. ISTHMUS. Includes proximal one-third of the duct.
   a. *Folded lumen lined with simple columnar epithelium, some cells of which are ciliated.* Ciliated cells become less numerous as the uterus is neared.

b. Muscle consists of an inner circular and an outer longitudinal layer of smooth muscle. *Circular layer is best developed.*

c. Blood vessels conspicuous in the outer layer of muscle and in the connective tissue.

d. May show a serous layer with flattened mesothelial cells.

e. Though the isthmus is about the same size as the ductus deferens and the ureter, it can be distinguished from them as follows: the Fallopian tube alone lacks an inner longitudinal layer of muscle, *the muscularis of the uterine tube is looser than in the ductus deferens,* and the outer longitudinal muscle of the Fallopian tube spreads out into the surrounding tissue in a way that is peculiar to it.

D. UTERUS.

1. ENDOMETRIUM (MUCOSA).

a. CORPUS AND FUNDUS during the interval phase.

(1) *Simple columnar epithelium, may be shorter or taller in places, some cells ciliated; mucous cells absent.*

(2) *Uterine glands are slender tubular structures.*

(3) Tunica propria around glands contains many nuclei and lymphocytes.

(4) The endometrium of the corpus and fundus undergo cyclic changes during the child-bearing period. In general these changes are in the nature of preparation for pregnancy. Four phases are distinguished.

(a) Interval (resting uterus) phase. Structure is described above under a, 1, 2, 3.

(b) Premenstrual (progravid) phase.

(*1*) Uterine glands increase in extent. Blood vessels become engorged and whole layer is thick and spongy.

(c) Menstrual phase.

(*1*) Sloughing off of the upper three-fourths of the endometrium. Extravasation of blood occurs.

(d) Postmenstrual (proliferative) phase.

(*1*) A period of repair in which there is a gradual return to the interval phase.

b. CERVIX.

(1) Mucosa somewhat thicker than that of corpus and fundus.

(2) Simple columnar epithelium, ciliated in places. *Glands are of the mucous type,* considerably branched, and may be cystic.

(3) Epithelium toward vagina is stratified squamous.
(4) *Lining of tall feather-like folds, plicae palmatae.*

2. MYOMETRIUM (MUSCULARIS).
   a. CORPUS AND FUNDUS.
      (1) *Dense smooth muscle, difficult to distinguish into layers.*
   b. CERVIX.
      (1) *The muscle is in somewhat more definite layers, consisting of an inner longitudinal, a middle circular, and an outer longitudinal layer of smooth muscle.*
3. PERIMETRIUM (SEROSA).
   a. Single layer of flattened cells (mesothelium) and small amount of fibroelastic tissue.

E. PLACENTA.

1. *The chorionic villi in transverse section appear as various sized islands of connective tissue surrounded by a single layer of deeply staining syncytial cells.* In the young human placenta, up to about two and one-half months of gestation, there are two layers of epithelium covering the chorionic villi; an outer syncytial layer and an inner cubical (Langhans) layer.
2. Blood is found inside and outside of the transversely sectioned villi.
3. *The larger villi show a considerable amount of dense connective tissue.*

F. VAGINA.

1. MUCOSA.
   a. *Unusually thick, stratified, squamous epithelium with low broad papillae.*
   b. *Mucosa thrown into coarse folds or rugae.*
   c. No gland present except in unusual instances where a few glands of the cervical type may be found in the posterior part (fornix).
   d. Tunica propria of dense connective tissue, often containing numerous lymphocytes.
2. SUBMUCOSA.
   a. Looser connective tissue than tunica propria, and also more vascular.
   b. Some histologists do not distinguish between a tunica propria and a submucosa in the vagina. There are authorities who list only one or the other and yet a third group who give both.
3. MUSCULARIS.
   a. *Inner circular and outer longitudinal layers of smooth muscle.* Muscle bundles so irregularly arranged that definite layers may not be apparent.

b. *Vascular spaces between the muscle bundles may give the appearance of erectile tissue.*

4. FIBROSA (ADVENTITIA).

a. Connective-tissue layer on the outside by which the vagina is attached to adjacent structures.

G. MAMMARY GLAND.

1. RESTING GLAND.

a. Bulk of gland consists of *dense connective tissue*, with a few scattered groups of ducts and their branches. The question of whether alveoli are present is unsettled. *The connective tissue is similar to that of the dermis, but it is free from sweat glands and hair follicles.*

b. *Deep-staining islands of ducts in the nonfunctional gland are very characteristic.*

c. Myoepithelial cells between the epithelium and basement membrane are especially prominent near the excretory ducts.

2. ACTIVE GLAND.

a. *The active gland shows the alveoli greatly expanded and filled with secretory material. The secretion is eosinophilic.* Connective tissue is considerably reduced when the gland becomes active.

b. *Drops of fat in the lumina of alveoli and ducts.*

c. Active mammary gland resembles thyroid, but the presence of ducts distinguishes it from an endocrine gland.

3. RETROGRESSIVE GLAND.

a. At the end of a period of lactation, a series of retrogressive changes (involution) takes place. Glandular structures are greatly reduced or disappear. Connective tissue elements increase and gland returns to nonfunctional condition.

b. After the menopause glandular elements are further reduced, until in advanced age they may become fibrous cords. The connective tissue is decreased by retrogression, and the whole gland becomes much reduced and shrunken. Remnants only of excretory ducts remain as evidence of glandular tissue.

Summary of the Histology of the Female Reproductive System

	Organ	*Epithelium*	*Muscle Layers*	*Connective Tissue*
	Ovary	*Germinal epithelium*, typically cuboidal	*Strands of smooth muscle cells in medulla*	*Fibroelastic. May be arranged in whorls in cortex. Loose in medulla*
	Oviduct (Uterine or Fallopian Tube)	Simple columnar Some cells are ciliated	Inner circular and outer longitudinal layers of smooth muscle	Subepithelial
UTERUS	**Corpus and Fundus**	Simple columnar. Some cells are ciliated	Smooth muscle difficult to distinguish into layers	Fibroelastic
	Cervix	Simple columnar. *Some cells are ciliated.* Lower end lined with stratified squamous	Smooth muscle in *more definite layers, consisting of inner longitudinal, middle circular, and outer longitudinal*	Fibroelastic
	Vagina	Stratified squamous	Inner circular and outer longitudinal layers of smooth muscle. Stratified muscle fibers form sphincter	Fibroelastic

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Endocrine (Ductless) Glands

A. THYROID.

1. An external layer of connective tissue envelops the gland, constituting a capsule. Connective-tissue septa extend into the substance of the gland.
2. *The parenchyma consists of cords, or clumps of cells, and rounded spaces, or follicles (vesicles), bounded by a simple epithelium, usually of cuboidal cells.* Cells of epithelium may vary from nearly flat to high columnar, depending on the activity of the gland. *The nucleus is spherical. Within many follicles there is a hyaline material which stains deeply with eosin, and is termed "colloid."*
3. No basement membrane. Cells rest on reticular tissue.
4. *Superficially, the thyroid may resemble certain phases of the mammary gland, but note the absence of ducts in the thyroid. The size of the follicular units may suggest lung but in the thyroid each space is completely closed and thus there are no incomplete septa.*
5. Some variations occur in the histological structure of the human thyroid throughout life until advanced age.

B. PARATHYROID.

1. Each parathyroid consists of a *mass of densely packed epithelial cells which may be arranged in cords.* Between cells there is a framework of reticular fibers, with many anastomosing sinusoidal capillaries. Two types of cells compose the cords:
   a. *Principal (chief) cells, nongranular, poorly staining, with large vesicular nuclei.*
   b. *Oxyphil (acidophil) cells, with small deep-staining nuclei and eosinophilic cytoplasm.* Somewhat larger than principal cells. Do not occur in some animals (cat, rat, dog) and are not present in man until end of first decade of life.
2. Isolated, or islands of, fat cells frequently present.
3. Surrounded by a thin fibrous capsule but no pia mater present as in the epiphysis. Reticular framework with many anastomosing sinusoidal capillaries.

4. *Superficially may resemble lymphoidal tissue, but cells in parathyroid are larger and have more cytoplasm.* Furthermore, they can be recognized as definitely epithelial in nature when examined under high power.
5. Occasionally embedded in the thyroid.
6. "Colloid" sometimes present.
7. Gland varies in histological structure with age.

C. ADRENAL (SUPRARENAL) GLANDS.

1. A connective-tissue capsule surrounds the gland.
2. *The gland is distinctly divided into cortex and medulla.*
3. The *cortex* is divided into the following zones:
   a. ZONA GLOMERULOSA. *An outer zone lying immediately beneath the capsule, in which the cells present an arrangement of irregular, rounded masses.*
   b. ZONA FASCICULATA. *An intermediate zone in which the cells are arranged in parallel columns.* May appear spongy due to the fat having been dissolved out of the cuboidal cells.
   c. ZONA RETICULATA. An inner zone in which the cells appear in the form of *branching and anastomosing cords.*
4. *The medulla is a narrow area which stains darker with hematoxylin than does the cortex, and occupies the middle portion of the gland. It consists of irregular masses of cells separated by thin-walled blood spaces (sinusoids).*

D. HYPOPHYSIS (PITUITARY GLAND).

1. Examined by low power, *the hypophysis is a thickly capsulated gland and can be divided into four parts; three divisions are distinguishable by their general color reaction with eosin and hematoxylin.*
   a. *The pars distalis (anterior lobe) distinctly eosinophilic (pink).*
   b. *The pars intermedia and pars tuberalis tend to be basophilic (blue).*
   c. *The pars nervosa (posterior lobe) staining but little and appearing fibrous rather than cellular.* In early embryonic stages the pars nervosa contains a cavity. In man and many other mammals, the cavity becomes obliterated although it persists in the adult cat.
2. With special staining technics, the following histological details of the four parts may be identified.
   a. PARS DISTALIS (ANTERIOR).
      (1) *Chief (reserve) cells or chromophobes.* Small cells with rounded nuclei and a small amount of cytoplasm which stains faintly with the basic dyes.

(2) *Eosinophilic (alpha) cells or acidophiles.* Are somewhat larger than chief cells and have a densely granular cytoplasm. Acidophiles stain readily with eosin in routine preparations.

(3) *Basophilic (beta) cells or basophiles.* Large irregular cells, which have a densely granular cytoplasm that stains with the basic dyes. They are difficult to identify in ordinary hematoxylin-eosin preparations.

b. PARS TUBERALIS.

(1) This lobe caps the pars distalis. The pars intermedia and the pars tuberalis have a similar arrangement of cords and blood vessels. *The cell cords frequently become hollowed out to form irregular cavities (vesicles) which are most common in the pars tuberalis,* less frequent in the intermediate lobe, and only occasional in the pars distalis. The lumens of these contain a "colloid" material similar in appearance and staining reaction to that found in the thyroid follicles.

(2) The cells of the pars tuberalis are cuboidal and are faintly basophilic.

c. PARS INTERMEDIA.

(1) Rudimentary in man and ape, but in most mammals it appears as a well-developed layer.

(2) The basophilic cells in the pars intermedia tend to form vesicles, which in many instances contain a hyaloid substance resembling in appearance the colloid of the thyroid.

(3) Note the narrow space, or cleft (interglandular), between the anterior and posterior lobes. With advancing age this tends to be obliterated.

d. PARS NERVOSA (POSTERIOR LOBE).

(1) Fibrous, with a scattered intermingling of branched cells of glial nature. They differ from neuroglia cells in that their cytoplasm contains fat droplets. Bucy named these pituicytes. These cells are indistinct in routine preparations.

(2) *Resembles nervous tissue.*

e. PHARYNGEAL HYPOPHYSIS.

(1) This gland occurs in the vault of the nasopharynx of man.

(2) Same structure as the pars distalis.

E. ISLETS OF LANGERHANS (PANCREATIC ISLANDS).

1. Spheroidal aggregations of pale-staining polyhedral cells.

2. With special fixation and staining, three distinct types of cells have been demonstrated.
3. *Not alveolar in character like the rest of the pancreas.*

F. CORPUS LUTEUM OF OVARY.

1. Described on p. 162.

G. INTERSTITIAL CELLS OF TESTIS.

1. Described on p. 150.

H. EPIPHYSIS (PINEAL BODY, CONARIUM).

1. Fibrous capsule derived from the pia mater.
2. *Numerous fibrous-tissue processes and septa pass into the gland from the capsule, dividing it into rounded lobules.*
3. The pineal cells are mainly apparent by their nuclei. Details of pineal cells are best observed in preparations stained by a special silver method.
4. "*Brain-sand granules*" (*corpora arenacea; psammoma bodies*), *dark, laminated, calcareous concretions, may be conspicuous.* These calcareous bodies are almost always present, even in infancy.

I. THYMUS.

1. This organ, although often discussed with the endocrine glands, is described on p. 84.

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Eye

A. CORNEA.

It is composed of five layers, which, from without inward are:

1. CORNEAL EPITHELIUM. On the anterior surface it is stratified squamous.
2. BOWMAN'S MEMBRANE (ANTERIOR ELASTIC MEMBRANE). This is a relatively thick basement membrane on which the epithelium rests.
3. SUBSTANTIA PROPRIA (CORNEAL STROMA). This forms about 90 per cent of the thickness of the cornea. Consists mostly of collagenous fibers which are arranged in lamellae running parallel to the surface.
4. DESCEMET'S MEMBRANE (POSTERIOR ELASTIC MEMBRANE). It is an elastic membrane on the posterior surface of the substantia propria.
5. CORNEAL ENDOTHELIUM. This is composed of thick squamous cells. The cornea proper is devoid of blood vessels.

B. SCLERA.

1. EXTERNAL LAYER (SCLERA PROPER).
   a. This layer consists of elastic and flat collagenous fibers which run in various directions parallel to the surface
2. INTERNAL LAYER (LAMINA FUSCA).
   a. Contains a varying number of branched pigment cells. More elastic fibers than in the external layer.

C. CHOROID (CHORIOID).

From without inward the following layers can be distinguished:

1. SUPRACHOROID LAYER (LAMINA SUPRACHORIOIDEA).
   a. Thin membranes or lamellae of fine connective tissue containing chromatophores between and in the membranes.
2. VESSEL LAYER (LAMINA VASCULOSA).
   a. Consists of numerous large and medium-sized arteries and veins. The space between vessels are filled with *loose connective tissue*. Some of the cells are pigmented.

3. CAPILLARY LAYER (LAMINA CHORIOCAPILLARIS).
   a. Consists of a capillary network.
4. BRUCH'S MEMBRANE (LAMINA BASALIS, LAMINA ELASTICA, LAMINA VITREA).
   Under most favorable conditions two layers may be distinguished:
   a. OUTER LAYER.
      (1) Thin layer of elastic fibers.
   b. INNER LAYER.
      (1) Homogeneous and thicker than outer.

D. THE CILIARY BODY.

It is formed by a thickening of the choroid in front of the ora serrata. Thus, from without inward, is found:

1. SUPRACHOROID AND CILIARY MUSCLE. Smooth muscle fibers present in the suprachoroid increase in amount in the ciliary body. The muscle fibers are oriented in three directions: meridional, radial, and circular layers.
2. VESSEL LAYER. It consists for the most part of veins.
3. GLASSY MEMBRANE (LAMINA VITREA). Continuous with the same structure in the choroid but consists of three layers
4. PIGMENT EPITHELIUM. It is a continuation of the pigment layer of the retina.
5. CILIARY EPITHELIUM. It represents a continuation of the sensory portion of the retina.
6. INTERNAL LIMITING MEMBRANE. This is a very thin structureless membrane.

E. IRIS.

1. ANTERIOR SURFACE.
   a. Covered by a single layer of mesenchymal epithelium and sometimes termed the *endothelium* of the iris. Difficult to demonstrate in sections.
2. STROMA.
   a. The *anterior border layer* has a *loose connective tissue* containing stellate cells. It contains no blood vessels. The amount of pigment varies from none to large amounts. The color of the iris depends upon the thickness and degree of pigmentation of this layer.
   b. The *vessel layer* contains many blood vessels between which are loose connective tissue and stellate cells. Two groups of smooth muscle

are present: the *sphincter pupillae* just within the pupillary border, and the *dilatator pupillae* from the pupillary border to the root of the iris.

3. POSTERIOR SURFACE.
   a. Covered by the internal *pigment epithelium* or pars iridica retinae.

F. RETINA. Largely of nervous elements.

1. VISUAL PORTION (PARS OPTICA). From without inwards the following layers can be distinguished:
   a. PIGMENTED EPITHELIAL LAYER.
      (1) Consists of hexagonal-shaped cells when seen from the surface which contain the *pigment melanin.*
   b. LAYER OF RODS AND CONES.
      (1) Consists of *elongated, cylindrical-shaped cone cells* and *rod cells* which are shorter and stouter.
   c. EXTERNAL LIMITING MEMBRANE.
   d. OUTER NUCLEAR (GRANULAR) LAYER.
      (1) *Nuclei of the rod and cone cells present.*
   e. OUTER PLEXIFORM (MOLECULAR, RETICULAR) LAYER:
      (1) Fibrous.
   f. INNER NUCLEAR (GRANULAR) LAYER.
      (1) *Nuclei present.*
   g. INNER PLEXIFORM (MOLECULAR) LAYER.
      (1) Fibrous.
   h. LAYER OF GANGLION CELLS.
   i. LAYER OF OPTIC NERVE FIBERS.
   j. INNER LIMITING MEMBRANE.

G. LENS.

1. Surface of lens is covered by a homogeneous capsule.
2. Within the capsule the anterior surface of the lens is lined by an epithelium of a single layer of cuboidal cells which are taller toward the equator.
3. Lens fibers consist of elongated six-sided (hexagonal) prisms. When first formed, the fibers are short.

H. VITREOUS BODY.

1. This consists of a scanty network of fibers and connective-tissue cells. In fresh condition the substance of the vitreous body has a gelatinous

consistency. In fixed sections it shows a network of fine fibrils with its meshes filled with a clear substance.

I. OPTIC NERVE.

1. CROSS SECTION OF ENTIRE NERVE.

a. *Large bundles of transversely cut nerve fibers, large and medullated, but without neurolemma.*

b. *Fibers are gathered into bundles (fasciculi) surrounded by interfascicular connective tissue.*

c. Surrounded from within outward by pia mater, arachnoid, and dura mater membranes.

d. Subdural space is relatively large.

e. Middle portion of optic nerve occupied by central artery and central vein.

f. *The optic nerve is generally considered, as indicated above, to be divided into fasciculi. However, it may be considered as a single large funiculus of which the pia is the perineurium and the interfascicular tissue, the endoneurium.*

J. EYELIDS.

1. *Tarsus* (*tarsal plate*) is a plate of very dense connective tissue which supports the lid.
2. *Tarsal* (*Meibomian*) *glands.* These are sebaceous glands. Each consists of a long straight central duct surrounded by numerous alveoli which open into it. This characteristic of the eyelid is one of the best identifying features.
3. Hair follicles usually present.
4. Accessory lacrimal glands may be observed.

K. LACRIMAL (LACHRYMAL) GLANDS.

1. This gland bears a very close resemblance to the parotid gland, but differs as follows:

a. *The lumina of the alveoli are generally larger than in the parotid.*

b. Dark-staining glandular cells have typically a narrower columnar shape than those of the parotid.

c. Between the glandular cells and the basement membrane are numerous basket (basal, myoepithelial) cells.

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Ear

A. EXTERNAL EAR.

1. AURICLE (PINNA).
   a. *Yellow elastic cartilage in center.*
   b. *Connective tissue outside the cartilage.*
   c. Thin skin on both sides with hair follicles and sebaceous glands.
   d. Sweat glands are scarce and small.
2. EXTERNAL AUDITORY MEATUS.
   a. In its outer part, walls are formed by continuation of the cartilage of the auricle and in the inner portion by the temporal bone.
   b. Thin skin lines the walls. Hair follicles, sebaceous glands, and ceruminous glands are present in the outer part.
3. TYMPANIC MEMBRANE (EAR DRUM).
   This is a thin membrane which separates the external ear from the middle ear. Some authors classify it as a part of the middle ear.
   a. The outer surface is lined by a thin layer of skin.
   b. The fibrous portion between the outer and inner epithelia consists of collagenous fibers and a thin network of elastic fibers. The outer layer is radially arranged. The inner layer is circularly arranged.
   c. The inner surface is covered by a single layer of flattened squamous epithelium.

B. MIDDLE EAR.

1. TYMPANIC CAVITY.
   a. The epithelium is generally simple squamous. In several places, especially near the opening of the auditory tube and near the edge of the tympanic membrane, it is cuboidal or columnar.
   b. The three ear bones or auditory ossicles are in this cavity. From the exterior to interior they are malleus, incus, and stapes.
2. AUDITORY (EUSTACHIAN) TUBE.
   a. BONY OR OSSEOUS PART.
      (1) Epithelium is ciliated columnar.

b. CARTILAGINOUS PART.
   (1) In the portion nearer the pharynx, the epithelium is pseudostratified ciliated.
   (2) Glands are present near the pharynx.

C. INNER EAR (LABYRINTH).

1. VESTIBULE.
   a. This is an irregular, oval-shaped cavity.
   b. The lateral wall, which forms the medial wall of the tympanic cavity, is pierced by two small openings or "windows": the fenestra cochleae (rotunda, tympanica) and the fenestra ovalis (vestibuli).
2. SACCULE.
   a. This sac-like structure occupies the lower anterior part of the vestibule.
   b. The outer layer consists of fine connective tissue, in which branched pigment cells are often found.
   c. The epithelium, which is flattened, is separated from the connective tissue by a distinct membrane.
3. UTRICLE.
   a. This has an oblong, transversely compressed, form, and occupies the upper posterior part of the vestibule. This is larger than the saccule.
   b. Structure same as that of the saccule.
4. MACULAE.
   a. The maculae represent local thickenings of the membranous walls, each covering an area approximately 2 mm. by 3 mm. in extent, and forming an elevation into the endolymphatic space.
   b. These maculae consist of supporting or sustentacular cells and hair cells. The first appear slender and columnar. The latter appear as short flasks with rounded bottoms that contain nuclei.
5. SEMICIRCULAR CANALS.
   a. These three canals are long loop-shaped tubes. Each lies in a different plane; namely, the frontal or superior, posterior or sagittal, and the lateral or horizontal.
   b. The membranous semicircular canals have a slightly oval cross section. Their convex surface is closely adjacent to the periosteum, while their concave surface is surrounded by a perilymphatic space with numerous trabeculae.
   c. Structurally the walls are similar to those of the utricle and saccule.

6. AMPULLAE.
   a. These consist of three enlargements of each semicircular canal where it opens into the vestibule.
   b. In a longitudinal section the crista is cut in cross section and appears as a high rounded prominence occupying about one third of the lumen.
   c. In a cross section the crista is cut longitudinally, is highest in its middle part, and slopes down toward the side walls of the ampulla.
7. COCHLEA. This is a spirally coiled tube.
   a. RADIAL SECTION.
      (1) Axis of the cochlea appears as a broad and short conical pillar of spongy bone, the modiolus. Blood vessels, surrounded by connective tissue and bundles of the cochlear nerve, penetrate through numerous openings into the bony substance of the modiolus. A spiral ganglion with its bipolar receptor neurons may be seen.
      (2) Upper portion (scala vestibuli).
         (a) Cavity surrounded by the inner zone of the spiral lamina (the osseous spiral lamina), the vestibular membrane, and the upper periphery of the osseous wall.
      (3) Cochlear canal (ductus cochlearis).
         (a) Between the upper and lower portion.
         (b) It is separated from the upper portion by the vestibular membrane, the membrane of Reissner.
         (c) It is separated from the lower portion by a part of the osseous and the whole of the membranous spiral lamina or basilar membrane.
         (d) This duct is triangular with the acute angle directed inward.
         (e) The internal spiral sulcus has the shape of the letter "C."
      (4) Lower portion (scala tympani).
         (a) Cavity bounded by both the osseous and membranous spiral laminae, and by the lower periphery of the osseous wall.
         (b) Basilar membrane (membranous spiral lamina) is greatly thickened and forms a triangular mass of connective tissue.
8. ORGAN OF CORTI.
   a. In radial section it has the form of an irregular trapezoid prominence bulging into the lumina of the cochlear duct.

b. There are different types of supporting cells but all appear *tall and slender*, extending from the basilar membrane to the free surface of the organ of Corti.

c. The hair cells on the free surface have short, rigid, bristlelike outgrowths. The two types have a short cylindrical shape with rounded bottom that contains a nucleus.

9. TECTORIAL MEMBRANE.

a. It projects from the spiral lamina over the cells of the organ of Corti.

b. Composed of a homogeneous, jelly-like, ground substance and numerous fine spirals.

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Olfactory Organ

A. OLFACTORY EPITHELIUM.

1. EPITHELIUM.

It is of the pseudostratified columnar type. The surface cells are of two kinds:

a. OLFACTORY CELLS (BIPOLAR GANGLION CELLS).

(1) Bipolar nerve cells of fusiform shape with *several rows of spherical nuclei.*

(2) The round nuclei occupy a zone between the nuclei of the supporting cells and the connective tissue.

(3) A cylindrical process extends from the peripheral part of each cell to the surface.

(4) Basally the olfactory cells pass directly into the axis cylinders of the olfactory nerves and collect to form the fila.

b. SUPPORTING CELLS (SUSTENTACULAR).

(1) These appear tall and slender.

(2) *The nuclei are oval in shape. Two or three rows of these oval nuclei are seen in sections.*

(3) The upper part of the cell contains pigment granules which give the epithelium its brownish-yellow color.

(4) Basal cells lie between the bases of the supporting cells. They appear conical with branching processes and dark staining nuclei.

2. TUNICA PROPRIA.

a. Connective tissue consists of collagenous and elastic fibers. Contains a rich plexus of blood capillaries. In the deep layers there is a *plexus of large veins* and lymph capillaries.

b. *Bowman's glands* (olfactory).

(1) These are in the tunica propria.

(2) They are of the branched tubular type and *appear serous-like.*

c. *Mixed serous and mucous glands.*

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Taste (Gustatory) Organ

The organ of taste consists of the taste buds of the mucosa of the tongue and epiglottis.

A. STRUCTURE OF TASTE BUDS.

1. These are barrel-shaped groups of cells embedded in the stratified epithelium in which they occur. Each taste bud is connected with the surface by a small opening, the gustatory pore. Two types of epithelium are present:
   a. SUPPORTING (SUSTENTACULAR) CELLS.
      (1) Tall columnar, somewhat crescentic in outline. They are roughly parallel to the bud axis, that is, they are arranged like the sections of an orange.
   b. TASTE (NEUROEPITHELIAL, GUSTATORY) CELLS.
      (1) Slender, elongated cells ending externally in hairlike processes. *The elongated dark-staining nuclei are placed in the midportion of the cells.* These cells are centrally located and parallel to the long axis of the bud.

B. GUSTATORY NERVES.

1. The terminal arborizations of the facial and glossopharyngeal nerves end in contact with the taste cells.

B. MAIN DISTRIBUTION OF CARTILAGE.

1. HYALINE CARTILAGE.
   a. Preforms all bones except flat bones of face and skull.
   b. Nasal cartilages.
   c. Most of the laryngeal cartilages.
   d. Tracheal and bronchial cartilages.
   e. Costal cartilages.
   f. Some articular cartilages.
   g. Epiphyseal cartilages until epiphysis joins diaphysis and xiphoid process.
2. YELLOW ELASTIC CARTILAGE.
   a. Auricle (pinna).
   b. Eustachian tube.
   c. Epiglottis.
   d. Part of arytenoid, corniculate, and cuneiform cartilages.
3. *WHITE FIBROCARTILAGE.*
   a. Intervertebral disks.
   b. Some articular cartilages.
   c. Symphysis pubis.
   d. Ligamentum teres of femur.
   e. Glenoid ligament of shoulder and cotyloid ligament of hip.
   f. Interarticular cartilages of many joints as the clavicle, sternum, lower jaw, knee, etc.
   g. Lines tendon grooves of the bones.

Glossary

Acidophilic. Referring to a tissue which has an affinity for an acid dye. An acid dye is a salt of a mineral base (generally sodium) and an organic acid which is colored.

Acinus. The terminal portion of a gland which is round or oval in shape and which possesses a narrow lumen Often used synonymously with **alveolus.**

Adelomorphous. Not having a clearly defined form, such as the chief cells of the stomach.

Adventitia. An external layer consisting of loosely arranged connective tissue.

Alveolus. The terminal portion of a gland which is spherical or oval, and which possesses a conspicuous lumen. Often used synonymously with **acinus.**

Ameloblasts (Ganoblasts, Adamantoblasts). Enamel-forming cells.

Anastomose. To join by connecting branches as nerves, or to open one into another, as blood vessels and lymphatics.

Apocrine Glands. Glands which produce their secretion by disintegration of the free ends of the cells that line the alveolus.

Areola. Any minute area or minute space in areolar tissue.

Areolar Tissue. A connective tissue composed of white and yellow elastic fibers which interlace in all directions.

Argyrophilic. Having an affinity for silver stain.

Artifact. Tissue that has been mechanically altered from its natural state. Also, anything added which is not normally present.

Autolysis. The self-digestion of cells by the action of their own enzymes.

Basement Membrane (Membrana Propria, Basal Membrane). The delicate transparent layer underlying the epithelium of mucous membranes and secreting glands.

Basophilic. Referring to a tissue which has an affinity for a basic dye. A basic dye is a mineral salt (generally a chloride) of an organic base which is colored.

Brunner's Glands. Appearing in the wall of the duodenum in the region of the pyloric sphincter.

Brush Border. Nonmotile, hairlike outgrowths which stand upright, in the fashion of a dense brush, on the free surface of an epithelium.

Cell. A spatially limited mass of protoplasm, containing a nucleus. The cell is the structural, functional, hereditary, and developmental unit of life. It is the minimal structural unit of protoplasm in an organism which can carry on all the vital functions.

Cell Membrane. The outer limit of the cell consisting of either a surface tension membrane or a distinct membrane.

Centro-acinous Cells. Cells of the terminals of the intralobular ducts continued into the acini of the pancreas.

Chromophil. An easily stainable structure.

Chromophobe. Staining very poorly or not at all.

Cohnheim's (Kölliker's) Areas or Fields. Myofibrils arranged in small groups as seen in cross section.

Collagenous (White) Fibers. Extremely fine (1 to 12 microns in thickness) white fibers whose course is characteristically wavy. Collagenous fibrils are arranged in bundles.

Colloid. A state of matter in which minute particles are suspended in a liquid.

Connective Tissue. A tissue composed of cells and certain other material produced by the cells, which, in its simple form, binds organs and tissues together. In a broader sense, it includes cartilage and bone. Blood may also be considered a connective tissue.

Cortical. Relating to the cortex, which is the outer portion of an organ.

Cross Section (Transection). A structure cut across (crosswise) or transversely of the long axis.

Crypts of Lieberkühn (Intestinal Glands, Mucous Crypts). Slits between the duodenal villi which extend into the mucosa as far as the muscularis mucosae. Excretory ducts of Brünner's glands usually open into these crypts.

Cuneiform. Wedge-shaped.

Cuticle. A layer of more or less solid substance which may cover the free surface of an epithelial cell; also called **cuticular border.** It is formed as a secretion of the cytoplasm.

Cytogenesis. Cell development or reproduction.

Cytogenic Glands. Glands which produce a secretion, parts of which are living cells.

Cytology. The science which deals with the structure of cells.

Cytomorphosis. The series of changes in a cell, from its formation to its removal.

Cytoplasm. The living substance of the cell not including the nucleus.

Delomorphous. Having a definite form and shape, as the parietal cells of the stomach.

Demilunes (Crescents or Demilunes of Gianuzzi). A darkly staining cap of crescent-shaped cells surrounding a mucous alveolus.

Elastic Fibers. Homogeneous branched fibers which anastomose into loose networks. Much thinner than collagenous fibers. Yellowish color.

Endothelium. The lining of blood vessels, heart, and lymphatic vessels.

Eosinophilic. A cell or histologic structure having an affinity for eosins (pink dyes).

Epiphyseal Cartilage. The plate of cartilage between the epiphysis and main portion of the bone.

Epithelium. Usually a group of cells covering a surface. Even those exceptions which appear in the form of solid masses or follicles have their embryological origin from a surface tissue.

Extravasation. The escape, as of blood, from a vessel into the tissues.

Facet. A small face, usually of some geometrical form.

Fascia (*plural fasciae*). A fibroelastic tissue which surrounds and connects the muscles.

Fasciculus. A bundle of close-set fibers, usually muscle or nerve fibers.

Fenestrated. Having fenestrae or windowlike openings.

Fiber. A threadlike structure of organic tissue.

Fibrillae. Minute fibers.

Fibroblasts (Fibrocytes, Desmocytes). Common connective-tissue cells. Flattened, irregularly branched, cells with large oval nuclei.

Fibroelastic Tissue. Connective tissue composed of both white (collagenous) and yellow (elastic) fibers.

Funiculus. A small cordlike structure, such as one of the bundles of nerve fibers, the aggregate of which composes a nerve trunk.

Ganglion. Groups of nerve-cell bodies (cytons) at certain points in the course of peripheral nerve trunks.

Genitalia. The genitals, which are the organs of reproduction.

Germinal Center. A pale-staining area in the center of a lymph nodule or follicle. An area of active mitosis in which the lymphocytes are loosely packed.

H. & E. An abbreviation for hematoxylin and eosin stains.

Hair Follicle. The depression from which each hair grows.

Hassall's Corpuscle. Small bodies in the thymus. Named after A. S. Hassall, an English physician.

Haversian Canals. The freely anastomosing canals of the bone; they contain blood vessels, lymph vessels, and nerves. Named after Clopton Havers, English anatomist, 1650–1702.

Hematoxylin. A crystalline compound containing the coloring matter of logwood; used as a dye in microtechnic.

Hematoxylinophilic. A cell or histological structure having an affinity for hematoxylin.

Hilum. A depression at the entrance and exit of vessels, nerves, and ducts into a gland.

Histogenesis. The origin of a tissue; the development of the tissues of the body.

Histology. The branch of anatomy which deals with the minute structure of the tissues and organs, and the morphologic evidence of their functions. General histology is the study of the several fundamental tissues, while special histology deals with the minute structure of the organs.

Holocrine Glands. Glands in which the products accumulate within the cell itself, the cell finally dies and is discharged as the secretion of the gland.

Homogeneous. Of uniform structure. Opposed to heterogeneous.

Hyaline. Smooth, glassy-like in appearance.

Hypertrophied. An increase in size of a part or organ.

Hypertrophy. Excessive growth or development of an organ or part of an organ of an animal or plant.

Intercalated Disks. These are transverse bands across heart muscle fibers. However, they may extend only part way across a fiber and may be irregular or broken into "step-formations." They are usually indistinct in H. & E. preparations, but can be brought out clearly by staining with silver nitrate or other special stains.

Intercalated (Intercalary, Intermediate) Duct. A very small duct connected with an acinus or alveolus of a gland.

Interstitial. Pertaining to spaces between cells within tissues.

Intralobular. Within a lobule.

Keratin. A horny material.

Labial. *Relating to the lips, or any lip-shaped structure.*

Lacuna. A small hollow or depression.

Lamella. A thin sheet or scale.

Lobe. One of the subdivisions of an organ or other part of the body, bounded by fissures, connective tissue, septa, or other structural markings.

Lobule. A small lobe.

Longitudinal Section. A section cut lengthwise, in the direction of the long axis of a structure.

Lumen (*plural lumina*). The cavity or passageway of a tubular organ, as the lumen of the digestive or respiratory tracts.

Malpighian. Pertaining to a number of structures described by *Marcello* Malpighi, an Italian anatomist.

Matrix. An intercellular substance usually produced by the cells.

Meatus. A passage or opening.

Merocrine Glands. Glands in which the secretory cells remain intact throughout the cyclic process of formation and discharge.

Mesenchyme. A loose embryonic connective tissue derived chiefly from mesoderm, although some of its cells may have an ectodermal or entodermal origin.

Mesothelium. Lining of the serous cavities (pleura, pericardium, peritoneum).

Micron. One micron equals 1/1,000 of a millimeter.

Millimeter. One millimeter equals 1/1,000 of a meter.

Millimicron. One millimicron equals 1/1,000 of a micron.

Mucosa. Consists of an epithelium with some subepithelial connective tissue, which lines cavities that communicate with the exterior. In some cases, as in the digestive tract, the mucosa includes the muscularis mucosae.

Mucous. Pertaining to mucus.

Mucus. A lubricating substance composed of water and mucin, a glycoprotein.

Multicellularity. Consisting of many cells.

Myelin. A soft, complex, little-known mixture of various lipoids, forming the substance of the medullary sheath of nerve fibers. It forms a glistening white envelope around the axis cylinders.

Myelinated (Medullated). Having a sheath of myelin.

Myoepithelial Cells. Smooth muscle cells in certain glands which develop from the same epithelium as the glandular elements.

Myofibrils (Myofibrillae). Numerous longitudinal fibrils contained within the protoplasm of the muscle cell or fiber.

Neurolemma (Neurilemma). The outermost sheath of a nerve fiber.

Neuron (Neurone). The nerve cell composed of the cell body with all its processes.

Nodes of Ranvier. Nodes produced by constrictions on medullated nerve fibers at an interval of about 50 to 1,000 microns. Named after Louis Ranvier, French histologist, 1835–1922.

Nuclear Membrane. Thin film separating the nucleus from the surrounding cytoplasm.

Nucleus. More dense portion of the protoplasm of a cell, usually ovoid or globular in shape.

Odontoblasts. Dentine-forming cells.

Organ. A group of cells or tissues functioning as a unit for some special purpose.

Organ of Corti. A complex membranous structure in the cochlea, the organ of hearing. Named after Corti, an Italian anatomist.

Organ System. Organs associated structurally or physiologically for a general function.

Osteoblast. A bone-forming cell.

Osteoclasts. Large multinucleate cells usually associated with the resorption or dissolution of bone. Formerly believed to be bone destroyers, but there is no direct evidence to support this belief.

Paneth Cells. Large, granular, eosinophilic cells found at the blind extremity of the fundus of the intestinal glands (crypts of Lieberkühn).

Papillae. Any small nipple-shaped elevations.

Papillated. Covered by or made up of small buds or nipples.

Parenchyma. Specific tissue component of an organ.

Parietal. Relating to the wall of any cavity.

Perichondrium. A dense connective-tissue sheath which covers the surface of cartilage.

Periosteum. A modified connective-tissue covering of a bone.

Periphery. The part of the body away from the center, the outer part or surface.

Plica. A bend or fold.

Polychromatophilic. Referring to the ability of tissue to take stains of several kinds.

Polymorphonuclear. Having nuclei of many forms.

Protoplasm. The essential substance of all plant and animal cells.

Pseudostratified Epithelium. Generally, a simple columnar epithelium in which the form and position of the cells have been altered by compression, with the result that the nuclei are at different levels.

Reticuloendothelial System. [illegible] of different kinds of cells that have one physiological trait in common; namely, that all are phagocytic.

Rhombic. Having the form of a figure with parallel sides, but with the angles not right angles.

Ruga (*plural rugae*). A fold, ridge, or wrinkle.

Sarcolemma. A delicate membrane surrounding striated or skeletal muscle cells or fibers.

Sarcomeres (Inokommata). The portion of a muscle fiber between two Krause's membranes or Z disks.

Sarcoplasm. The fluid protoplasmic substance of skeletal muscle fibers.

Secretory Duct. Any one of the smaller ducts which are contributory to the excretory ducts of a gland.

Septa. Walls or partitions of connective tissue dividing an organ or structure into two or more parts.

Seromucous. Partly serous and partly mucous.

Serosa. Mesothelial cells resting upon a thin layer of connective tissue, which line cavities that do not communicate with the exterior. The uterus is exceptional in that, although lined by a serosa, it opens to the outside of the body.

Serous. Pertaining to, producing, or resembling serum.

Serum (*plural sera*). The fluid part of the blood and lymph remaining after coagulation.

Sinusoids. Large, irregular, tortuous, blood spaces which are comparable to capillaries in that their walls consist of scarcely more than an endothelial tube, but which differ from capillaries in that their lumina are of greater size.

Squamous. Scalelike.

Stellate. Star-shaped.

Stereocilia. The cilia are nonmotile (epididymis).

Stratified. Arranged in layers.

Stroma. The connective-tissue component of an organ.

[illegible]

plasmic processes.

Tactile. Pertaining to touch.

Terminal Bars. In various kinds of epithelia a dense cement substance closes the intercellular spaces.

Tissue. A group of cells of similar structure with intercellular substances (if any) which perform a specialized function.

Trabecula. A prolongation of a fibrous membrane forming septa or partitions.

Tunica Propria (Lamina Propria). A loose fibroelastic connective-tissue layer which may contain smooth muscle fibers and lymphoid tissue. The basement membrane of a mucosa rests upon the tunica propria.

Vertical Section. A plane directed perpendicularly to the surface of a structure.

Bibliography

BAILEY, SMITH, AND COPENHAVER: *Text-Book of Histology*, 11th ed., Baltimore, The Williams and Wilkins Co., 1944.

BREMER AND WEATHERFORD: *A Text-Book of Histology*, 6th ed., Philadelphia, The Blakiston Company, 1944.

COLE: *Text-Book of Comparative Histology*, Philadelphia, The Blakiston Company, 1941.

CONN: *Biological Stains*, Geneva, N. Y., Biotech Publications, 1940.

COWDRY: *Special Cytology*, 2d ed., New York, Paul B. Hoeber, Inc., 1932.

COWDRY: *Textbook of Histology*, 3d ed., Philadelphia, Lea and Febiger, 1944.

HEWER: *Text-book of Histology for Medical Students*, St. Louis, C. V. Mosby Co, 1938.

HILL: *A Manual of Histology and Organography*, 7th ed., Philadelphia, W. B. Saunders Co., 1937.

HOSKINS AND BEVELANDER: *Essentials of Histology*, St. Louis, C. V. Mosby Co, 1945.

JORDAN: *A Textbook of Histology*, 8th ed., New York, D. Appleton-Century Co., 1940.

KENDALL: *The Microscopic Anatomy of Vertebrates*, 2d ed., Philadelphia, Lea and Febiger, 1940.

KRAFKA: *Textbook of Histology*, Baltimore, The Williams and Wilkins Co., 1936.

LAMBERT: *Introduction and Guide to the Study of Histology*, Philadelphia, The Blakiston Company, 1938.

MAXIMOW AND BLOOM: *A Textbook of Histology*, 4th ed., Philadelphia, W. B. Saunders Co., 1942.

PIERSOL: *Normal Histology*, 15th ed., Philadelphia, J. B. Lippincott Co., 1932.

RAMÓN Y CAJAL: *Histology*, Baltimore, Wm. Wood & Co., (The Williams and Wilkins Co.), 1933.

SCHAFER: *Essentials of Histology*, 14th ed., Philadelphia, Lea and Febiger.

SOBOTTA-PIERSOL: *Textbook and Atlas of Human Histology and Microscopic Anatomy*, 2d ed., New York, G. E. Stechert & Co., 1930.